CALIFORNIA AGRICULTURAL EXPERIMENT STATION

THE PEACH TWIG BORER

Stanley F. Bailey

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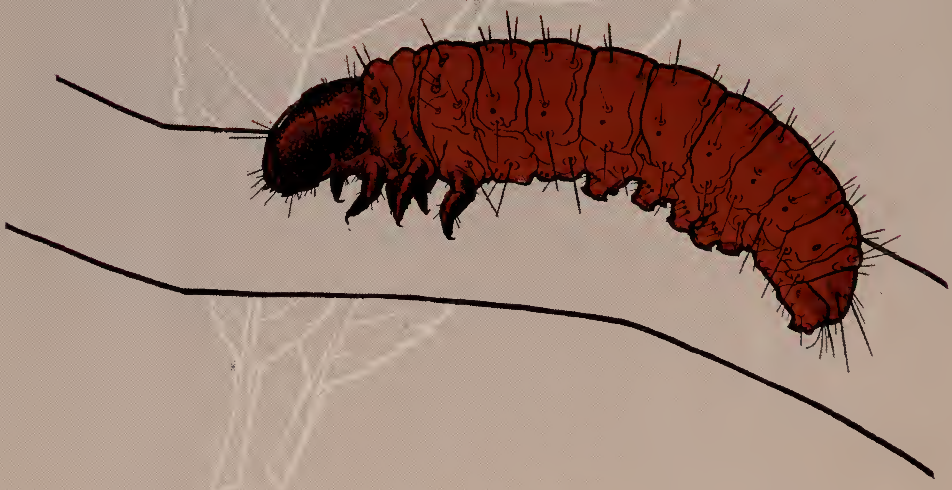

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This Bulletin, written for the grower, pest-control operator, and entomologist, describes the life history and annual cycle of the peach twig borer from the viewpoint of recently discovered biological facts. It discusses the injurious, seasonal habits of the pest on peaches, apricots, nectarines, plums, and almonds, and presents the difficulties in attempting to predict the annual degree of crop damage.

- The recommended control program is based on accumulated experimental data concerning the two chief sources of control:

> **CHEMICALS**—the principal means of controlling infestations in areas where annual loss occurs. Experimental data are given on dormant sprays and on early spring and summer applications. The effectiveness of DDT sprays is compared with that of standard sprays.

> **PARASITES**—also an important means of control. New data are given on the reduction of the pest by native parasites. Control by introduced parasites is also given, as well as its present limitations.

CONTENTS

THE PEACH TWIG BORER[1]

Stanley F. Bailey[2]

THE PEACH twig borer, *Anarsia lineatella* Zell., is a pest of major importance in peach growing. Considerable loss is also suffered every year to almonds, apricots, and plums, but not always in the same district nor on the same property. An annual spray program is necessary, therefore, especially on peaches, to prevent a serious increase of the insect.

The price of fruit and the size of the crop have considerable influence on the spray schedule and the subsequent amount of injury by the pest. For instance, as methods of grading and standards of almonds were modified, the relative importance of the peach twig borer increased on soft-shelled varieties of this crop.

The use of many new chemicals in the field of insect control has challenged the relative value and efficiency of the existing methods of control of this and of other insect pests. Because of the rapid change in methods of control, any recommendations set forth will be only temporary. For an established industry a middle course should be followed—for instance, a gradual change from established practice to more efficient and more economical methods as they are proven.

Although the biology of insects changes but little, new facts are discovered from time to time, which enable us to understand the problem better and to apply newer methods of control.

DISTRIBUTION

The peach twig borer occurs in many peach-growing states of this country. It is also known in Europe and the Old World. In California it is found in all peach- and almond-growing districts. The heaviest concentration of the pest is to be found in the upper San Joaquin and Sacramento valleys. South and west of this area, infestations are generally of less importance.

The peach twig borer has been recorded by the Insect Pest Survey Section of the United States Department of Agriculture, Bureau of Entomology and Plant Quarantine, from the following states: Alabama, Arizona, Arkansas, California, Colorado, Connecticut, Delaware, Georgia, Idaho, Illinois, Iowa, Kansas, Kentucky, Maryland, Massachusetts, Michigan, Mississippi, Missouri, Nebraska, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Utah, Virginia, Washington, and West Virginia.

In hibernacula (a hibernaculum, according to Webster's International Dictionary, is "a hibernating-case constructed of foreign materials by certain insects") the peach twig borer is readily transported on nursery stock, cuttings, and buds. It doubtless occurs in all areas where its deciduous host crops are cultivated.

HOSTS

The principal host plants of the peach twig borer are the peach and almond. In addition to these crop hosts are the apricot, cherry, nectarine, plum, and prune. In California, to our knowledge, this insect has never attacked any other crop or native plant.

ECONOMIC IMPORTANCE

Since the peach twig borer was first discovered in California about sixty years ago, it has annually been a pest of economic importance. As early as 1887, a 50 per cent loss of peaches was experienced

[1] Received for publication October 7, 1947.

[2] Associate Professor of Entomology and Associate Entomologist in the Experiment Station.

in some districts. Clarke (1902) wrote that "In some seasons this loss has aggregated as high as 30 per cent of the entire crop." During the years 1898 to 1901 the total loss was estimated at $1,373,000.

Essig (1926) reported that as much as 80 per cent of the late peaches was destroyed when control measures were not practiced.

The heaviest known loss from this pest occurred in 1931. In a study of the infestation in the Sacramento Valley, Mackie and Jones (1931) reported an average of 10.78 per cent infested fruits in the peach belt. Many individual properties in the Yuba City area suffered as much as 50 to 70 per cent damage. Since 1931, the injury has been spotty and irregular.

Economic factors in the soft-shelled almond industry have worked to focus attention on the losses caused by the twig borer. After a federal tolerance of 5 per cent on "bad meats" was established, shelling operations indicated that 90 per cent or more of the annual supply of bad meats was caused by the twig borer. From time to time "Almond Facts," the official publication of the California Almond Growers' Exchange, has referred to the seriousness of this pest. For example, the October, 1940, issue stated, "In considering the problem of the peach twig borer this year, it is interesting to note that the most heavily affected areas were in the Sacramento and San Joaquin valleys. The Paso Robles district remained virtually untouched, as is disclosed by the figures in the next column, which represent an average of deliveries containing over the 5 per cent tolerance. Not all districts are shown, the tabulation being merely a cross section of the state.

	Nonpareil	IXL	Ne Plus	Drake
	per cent	per cent	per cent	per cent
Arbuckle	41.5	23.4	6.0	35.5
Chico-Durham	31.5	33.7	5.6	11.5
Orland	47.8	52.8	23.0	32.8
Esparto	35.2	22.2	5.7	31.0
Contra Costa	7.9	1.8	1.2	....
Oakdale	23.7	22.6	....	1.8
Salida	16.8	17.8	1.8	1.4
Merced	4.4	1.7	0.6	2.2
Live Oak	71.2	53.0	11.1	59.2
Paso Robles	....	....	....	....
State-wide Average	27.3	29.2	9.9	17.1

From 1937 to 1942, in our experimental unsprayed plots (of Nonpareil) at Arbuckle, the percentage of injured meats varied from 1.5 to 35.0 with a six-year average of 12.5. The economic loss to the Nonpareil variety of almonds from the peach twig borer for the years 1933 to 1945 inclusive has been compiled for this publication by the Almond Growers' Exchange. This is presented in table 1. The injury to the IXL and to other varieties of almonds should be added to the total loss of $537,162 for the period shown in table 1.

The damage to plums occurs chiefly in the Vacaville, Penryn, Lodi, and Visalia districts. The so-called stem worms or small larvae which attack plums at harvest usually appear at the time the early varieties ripen, but in delayed seasons the damage occurs on later maturing varieties, such as Kelsey, Grand Duke, and President. Even in the seasons of heaviest infestation affected fruit on plums is rarely greater than 20 per cent. Here again, the local degree of injury varies greatly and is difficult to predict.

Conditions affecting injury to apricots are closely parallel to those on early plums. The damage to apricots is usually more severe in years of light crops, is spotty and unpredictable, but is not widespread.

As is true of the result of most injurious fruit insects, the presence of damaged fruits and nuts immediately increases picking and sorting costs. This expense is in addition to the loss through reduction in salable tonnage.

INJURY

The damage caused by the peach twig borer is twofold: killing the twigs and directly injuring the fruit. The former is of

Table 1: ECONOMIC LOSS TO NONPAREIL VARIETY OF ALMONDS FROM PEACH TWIG BORER*

Year	Total California almond production	Approximate amount of in-shell Nonpareil almonds based on deliveries to Exchange	Nonpareil meats based on estimated average meat content of 60 per cent	Worm-cut meats of Nonpareil from Exchange shelling operations	Damaged or worm-cut meats (Nonpareil)	Average in-shell returns to Exchange members for Nonpareil variety	Shelled equivalent return on Nonpareil meats: column 6 divided by 60 per cent meat content of Nonpareil variety	Loss per ton on worm-damaged meats based on one third recovery	Amount of loss
	tons	tons	tons	per cent by weight	tons	cents per pound	cents per pound	dollars per ton	dollars
1933....	12,900	3,870	2,322.0	1.20	27.86	13.0	21.7	289	8,052
1934....	10,900	3,706	2,223.6	1.34	29.79	14.75	24.6	328	9,771
1935....	9,300	3,348	2,008.8	3.36	67.49	20.2	33.7	449	30,303
1936....	7,600	2,204	1,322.4	5.89	77.88	27.5	45.8	611	47,585
1937....	20,000	7,000	4,200.0	1.19	49.98	17.2	28.7	383	19,142
1938....	15,000	4,800	2,880.0	7.49	215.71	15.5	25.8	344	74,204
1939....	19,200	7,296	4,377.6	0.34	148.83	13.5	22.5	300	44,649
1940....	10,200	3,264	1,958.4	4.53	88.71	19.7	32.8	437	38,810
1941....	5,000	1,850	1,110.0	8.34	92.57	44.4	74.0	987	91,366
1942....	22,000	8,800	5,280.0	1.0	52.8	26.7	44.5	593	31,310
1943....	16,000	5,120	3,072.0	1.9	58.36	44.9	74.8	997	58,185
1944....	21,000	9,450	5,670.0	1.2	68.04	44.9	74.8	997	67,836
1945....	23,800	9,044	5,426.4	0.3	16.27	44.7	74.5	993	16,156
Total	....	....	....	....	....	....	....	....	537,162

* Prepared from data supplied by California Almond Growers' Exchange.

Fig. 1.—Severe twig borer injury to young almond causes deformation by killing of terminals.

Fig. 2.—Wilted shoots of almond as seen on early spring growth. Twig borer larvae enter near the tip and burrow downward. Before reaching maturity, a single larva may attack several shoots. The damage is the same on all fruit trees attacked.

minor importance, but the latter—the economic loss to the fruit itself—is of major concern.

No damage is caused to the trees by the feeding of the minute larva under the bark, while forming the hibernaculum, nor its tunneling in the crotches for the short period in the spring before bloom. On two-year-old trees as many as 80 hibernacula have been found on one tree, where they had caused no apparent injury. However, the deformation and stunting of nursery stock, young orchard trees (fig. 1) and replants by such heavy infestations often become serious, especially on unsprayed trees.

Upon emerging from hibernation, the larvae migrate to the tips of the twigs where they burrow and often kill several before reaching maturity. This type of injury is seen on all the crop hosts—apricot, prune, plum, nectarine, peach, and almond. The more vigorous and rapidly growing varieties and individual trees escape serious stunting. The May brood attacks the lateral shoots which have been stimulated by the killing of the terminal bud earlier in the season. From this time on, the succulent and vigorous varieties exhibit more wilted shoots (fig. 2), and the slower-growing and nonirrigated trees begin to harden off and become less attractive to the worms.

On bearing trees, the damage to the fruit of all the host crops, with the exception of almonds, is essentially the same. The feeding injury to the fruit begins with the May brood and is usually evidenced by "bleeding" or sap droplets on the green fruit of almonds (fig. 3), plums, prunes, nectarines, peaches, and, to a lesser extent, of apricots. The larvae often make several attempts to penetrate the fruit, but rarely make entry at this stage of growth except in double fruit or in fruit with split pits (fig. 4). The relative amount of culls resulting from this injury in May is very small in comparison with the damage from the midsummer broods. On apricots, however, if the May brood is large, and has hatched later than normal, the infestation coincides with the ripening of early fruit. Then, considerable local injury results. The feeding of the twig borer on green almond hulls is of no concern. It occurs more often in dry-farmed orchards, as the tip growth hardens, than in irrigated sections.

Growers commonly speak of twig borer injury to ripe stone fruits as being caused by "stem worms" and "skin worms." Early varieties of plums and peaches, when attacked, usually show a high percentage of large larvae present at harvest. These larvae attack the majority of fruits near the stem end, where two fruits touch, or where leaves are stuck to the surface of fruit (figs. 3 and 4). When the larvae crawl about over the trees seeking early-ripening fruit, they migrate down the stems and usually enter the fruit at that point. Large larvae sometimes penetrate to the pit. An increasingly greater proportion of the small and newly hatched larvae called skin worms seek later-ripening varieties. They penetrate the skin of the fruit only a short distance, feed over an area of about 1/8 to 1/4 inch in diameter (fig. 5), and are seldom more than a third to half grown by harvest. As varieties of fruit ripen and are harvested, the moths migrate to adjacent orchards seeking unpicked fruit and, if successful, lay their eggs.

Many of the eggs are laid directly on the fruit, particularly if it has begun to ripen, rather than on the leaves, as earlier in the season. It can then be seen that, as the picking season advances, there is a progressively greater concentration of the twig borer on late varieties. Distinct broods or peaks of larvae hatching are no longer evident. Also, each day that picking is delayed, additional eggs are laid, more larvae hatch, and the feeding larvae extend their visible injury. This vicious circle results in a rapidly mounting loss at a time when it is practically impossible to use any control measures. The increased amount of worm-infested fruit

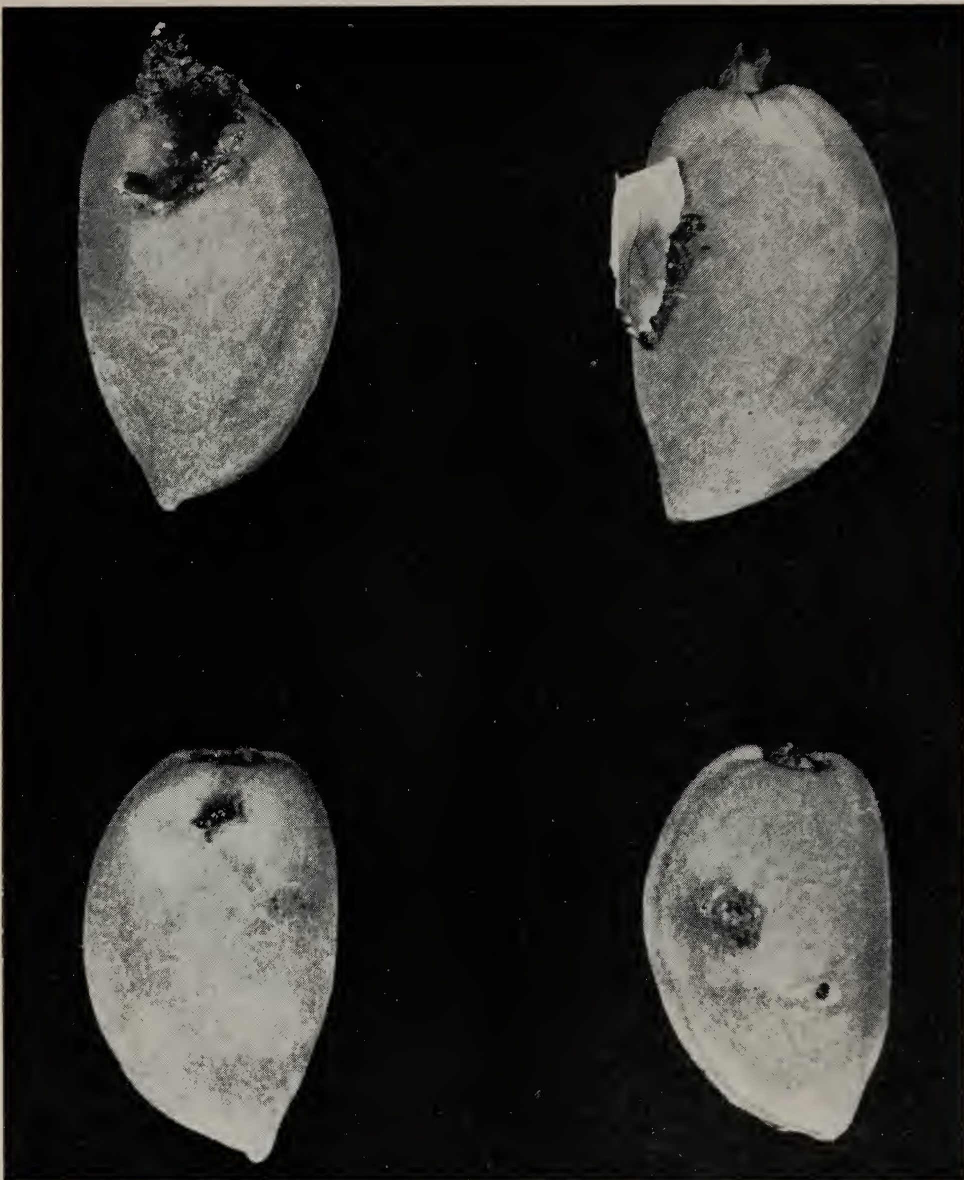

Fig. 3.—Twig borer injury by larvae to green Texas almonds early in June. Although the later midsummer brood feeds under the cracking hulls, it injures the meats of soft-shelled varieties only.

Fig. 4.—Sugar prunes injured by midsummer brood of twig borer larvae.

dropped by the pickers becomes evident as the picking progresses, especially in years of above-average infestation. In large fruit-growing districts the outside rows of an orchard nearly always show more damaged fruit than the inside rows. This happens because the moths, in their migration, alight at the margins first and deposit their eggs nearby.

The injury to almonds is different from that to stone fruits. Early in July the hulls begin to crack; then the moist interior of the hull and the surface of the nut are exposed to migrating larvae. Larval feeding is of no concern on hard-shelled varieties and, as the hulls dry up, the larvae mature rapidly. On the other hand, soft-shelled varieties are readily damaged by the midsummer brood as the larvae can easily penetrate the paper-shell covering and feed directly on the meat. This damage is done chiefly in July by one prolonged brood. At harvest time in August, a few larvae are found still feeding, but the great majority of those hatching after the nuts begin to mature go directly into the hibernacula and remain there. The twig borer larvae, rarely consume the meat; instead, they feed on the margins, end, or sides, which disfigures or blemishes the skin covering the meat (fig. 6). There is no known direct reduction in tonnage of

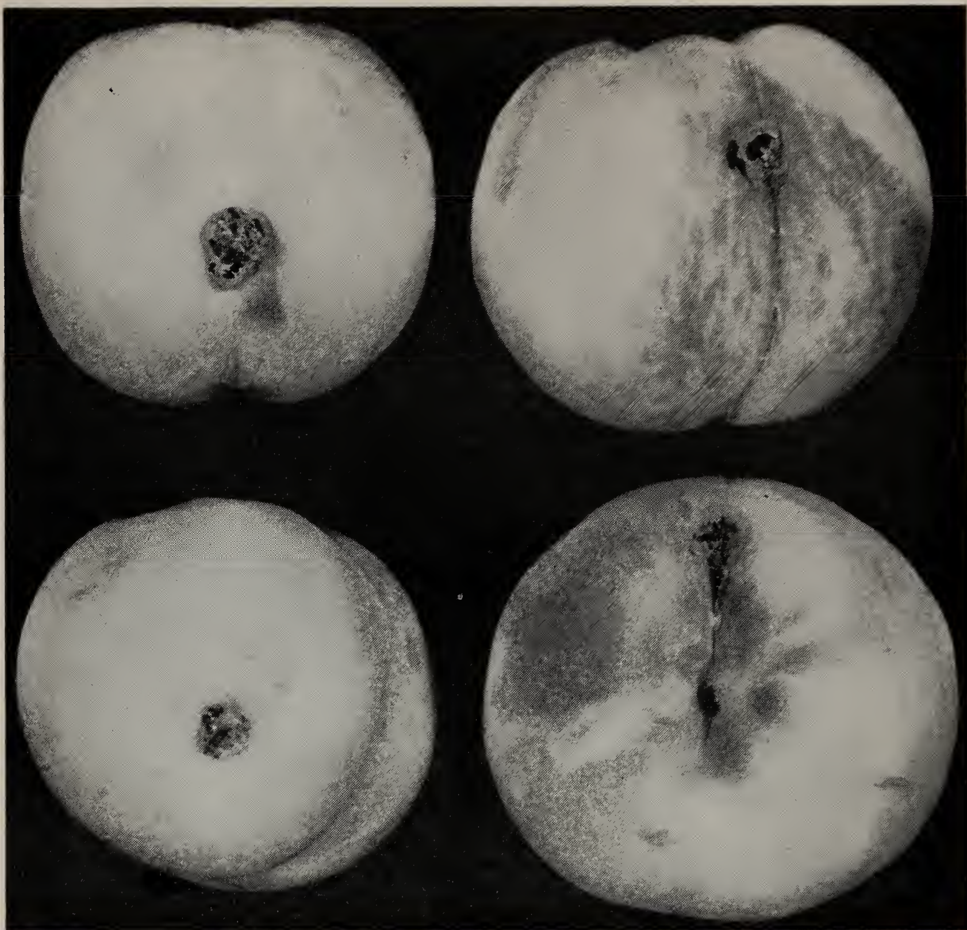

Fig. 5.—Simms peaches injured by peach twig borer larvae in early August. At this season, larvae of all sizes are often found with very small "skin" and "stem" worms predominating.

almonds brought about by the twig borer. The injury to the meats is of economic importance when it exceeds 5 per cent (under present government regulations), and, as has been discussed above, this condition does occur nearly every year in some districts.

DESCRIPTION

Adult. The adult moth (fig. 7) is dark gray with irregular spots and streaks of light and dark gray. It is about 8 millimeters, or $\frac{5}{16}$ inch, long with a wing expanse of twice its length. The head is bluntly rounded, as are the wings which, when not in use, are held roof-like over the body. The palpi curve back over the head and resemble horns. The male is slightly smaller than the female.

Egg. The egg is bluntly oval, and its surface is covered with reticulations. When first laid, it is yellowish white; later it turns orange. It measures about 0.4 millimeter in length and 0.2 millimeter in width.

Larva. The newly hatched larva is light yellowish brown with a black head. It is about 0.5 millimeters in length. The mature larva (figs. 8 and 9) is, on the average, 10 millimeters, or $\frac{3}{8}$ inch, long. It is reddish brown with black head and black cervical and anal plate. The yellowish-

Fig. 6.—Wilted shoots of almond, and worm-cut almond meats injured by twig borer larvae. Hard-shelled varieties of almond are rarely injured. Note pupa at extreme lower right in hull.

white intersegmental membranes offer sharp contrast with the segments.

Pupa. The pupa or chrysalis is naked, smooth, about 6 millimeters, or ¼ inch, long and dark brown (figs. 10 and 11).

LIFE HISTORY AND HABITS

Various authors have contributed to the life history and habits of *Anarsia lineatella* in California. Ehrhorn (reported by Marlatt, 1898), Clarke (1902), and Duruz (1923) made various observations of the insect, which included the fundamentals of the seasonal cycle and the outstanding biological characteristics. Jones (1935), however, published the most detailed and comprehensive study yet made. It is upon his study that we draw freely in the following discussion, and supplement it with our own studies carried on from 1937 to 1942 and again in 1946 and 1947. Jones studied the insect on peaches almost exclusively, and our work has been concentrated largely on almonds.

Fig. 7.—Adult twig borer moth. Natural size about ⅝ inch.

Length of Stages. The life history stages and their approximate length during the summer season are shown here:

	Days
Egg	5–7
Larva	10–20
Pupa	6–7
Adult (longevity) . . . . (in laboratory)	10

The great variation in the number of days for the larva occurs because larvae which feed entirely on green shoots or fruit develop faster than those which first tunnel under bark and later complete their growth on fruit and twigs. As would be expected during the cooler weather of spring and fall, the stages are somewhat prolonged.

The overwintering larval stage is, of course, not to be compared with the summer generations. The minimum longevity of larvae in the overwintering stage would be from mid-September, the time of hatching of the last eggs of the season, until earliest pupation the following spring—about April 15, or 7 months. Some individual larvae of this group live longer—perhaps 9 months—especially if they enter the hibernacula in midsummer and do not mature until late April, as happens in a delayed spring.

Habits of Moth. The adult *Anarsia lineatella* is the most difficult stage to collect and study. The number of moths seen and collected under natural conditions in the orchards is very small. There appear to be several reasons for the paucity of information concerning this stage, namely, the natural protective coloration of the moths, their nocturnal habits, small size, and short, irregular flight. In heavily infested peach orchards at picking time the moths become fairly numerous. They may be observed resting on all parts of the trees, in lug boxes, and even on the ground on clods and on fallen fruit. During the day, they rest quietly in the shade with the anterior portion of the body

slightly raised. When disturbed, they fly rapidly in a zig-zag course and alight only a few feet away. In addition to flying, they often run about jerkily over bark and leaves. Mating and egg laying have been observed only in cages.

Attempts to trap the moths by means of bait pens or by lights (Jones, 1935) have been unsuccessful. It does not appear

at Arbuckle in June, 1941, from which emerged 97 females and 112 males.

The amount of feeding done by the moths is very limited and irregular. In a number of instances in the field, moths have been observed feeding on nectaries at the base of leaves and on the moist flesh of injured fruits. In cages they feed readily on sugar and water solutions.

Fig. 8.—Dorsal or top view of mature twig borer larva. Natural color is reddish brown with a black head. Natural size about ⅜ inch.

Fig. 9.—Side view of mature twig borer larva. Natural size about ⅜ inch.

practical to try to obtain data on the flights of moths to aid in timing the spray applications.

The proportion of sexes appears to be about equally divided. G. L. Smith (unpublished notes) raised 126 moths from peaches at Yuba City in May, 1933; of these, 52 were females and 74 males. The writer collected 209 pupae in tree bands

The longevity of moths under natural conditions is unknown. In cages they survive from 3 to 20 days (G. L. Smith, unpublished notes) with an average of 10.3 days. Even under laboratory conditions with live plant material and with sugar and water available, we were unable to keep moths alive longer than 18 days. Without water, 100 per cent mortality occurred within 5 days.

Various workers have studied the moth under laboratory conditions and report the following facts:

The preoviposition period is from 1 to 4 days. More than half of the eggs depos-

ited in the life of a female are laid in the first half of its adult life. The largest number of eggs laid by one individual was 115.

Among other habits of the moth, the manner and place of egg laying are worthy of mention. In the spring the majority of the eggs are deposited on the twigs and leaves of the new growth. They are laid singly and are lightly cemented to the surface. On young trees, many eggs are laid on the bark in the crotches of new wood. As the fruit ripens, a majority of the eggs are deposited on the fruit. On peaches, particularly, eggs may readily be found in the fuzz. Here, a single moth may deposit 1 to 10 eggs in a square inch of fruit surface.

Nothing is known concerning parasites or enemies of the moth itself.

Egg Stage. As mentioned above, the eggs are deposited by the moth, more or less at random, on the surface of bark, twigs, leaves, and fruit. In cages, eggs are laid on paper, glass, or wood, but, if available, living plant material is preferred by the moths. Smith recorded careful observations on egg laying on peaches in May, 1933. Of 412 eggs located and marked, 98 per cent were laid on the fruit. On young trees, the writer has observed that the majority of the eggs are deposited on the bark, near the base of leaf clusters, or next to the midrib on the lower side of leaves. Oviposition has been observed in the daytime, but the greater number of eggs are laid at night because the moths are most active at dusk.

Fig. 10.—Twig borer pupa in place on section of bark removed from pruning scar. Left, rough, silken web and bark fragments covering pupa; right, underside of same bark section showing pupa (center) under web.

When the eggs are first laid, they are a pale cream color and gradually darken until, before hatching, they become a pinkish orange.

At the time of hatching, there does not appear to be a distinct line of cleavage of the shell. The larva breaks out the shell at one end, leaving an irregular opening in the area of its head.

There appears to be some natural mortality of the eggs but it is not high. Some fail to hatch from lack of fertilization or other causes. The predaceous thrips, *Leptothrips mali* (Fitch), in both the larval and adult stages in some orchards attacks a large number of twig borer eggs. If red spider eggs are also present, however, the thrips do not concentrate on the twig

borer eggs, and the mortality from this cause is therefore lower. The length of the egg stage varies considerably. It was as short as 4 days in very warm weather in late June, 1940. During this period, 172 eggs were laid on peach terminals. Of this number, 74 hatched and the remainder were attacked by thrips or were sterile. Of those that hatched, the length of incubation was as follows:

	Days
46	4
13	5
2	6
3	7
10	9
Average	5.00

From the data obtained by Smith and Jones, and that cited above, it can be seen that the time spent in the egg stage shortens from early spring to summer, with the extreme range from 4 to 18 days.

Fig. 11.—Pupae of the twig borer found clustered under tree protectors on young almond trees in late May.

Habits of Larva. There are two principal and distinct types of peach twig borer larvae: the overwintering larvae and their characteristics, and the feeding larvae of the midsummer broods. This latter group in turn is made up of two types of larvae: one that feeds on the bark and forms temporary hibernacula, then later migrates to fruit and completes its growth; and another that feeds entirely on green shoots and fruits. The habit of

tunneling into the young twigs has given the insect its accepted common name of twig borer. To distinguish it from the beetle, *Polycaon confertus* Lec. (the branch and twig borer) the prefix "peach" should be used. In this report, the term twig borer refers only to *Anarsia lineatella.*

At the beginning of the hibernating season in October, there are two sizes of larvae in the hibernacula: very small newly hatched individuals, and the second-instar larvae hatched from midsummer broods which have been under the bark for several weeks (table 3). Some feeding continues in tunnels under the bark until cold weather, but the larvae increase in size very slowly. Counts made

Fig. 12.—Peach twig borer larva in its hibernaculum under bark of two-year-old twig.

of the larvae during the late fall show the proportion of the first and second instars (table 3). By mid-November all feeding stops. Then the larvae enclose themselves in the silken-lined hibernating tubes (fig. 12) and remain dormant for 2 to 3 months.

The majority of these tubes or cells are

constructed in the corky, rough bark or cracks in the crotches or on lateral limbs of one- to four-year-old wood (fig. 12). Occasional chimneys may be found at the base of buds, at the margins of old scars, and even on the stems of fruit. The depth (or diameter) of the tunnel is rarely more than 1 millimeter and the length of the hibernaculum is usually from 2 to 5 millimeters. The depth to which the larvae penetrate beneath the bark is rarely more than 2 millimeters or about $\frac{1}{16}$ inch. Not all hibernacula have chimneys and some show no external evidence of their presence.

During the dormant period, the external parts of the hibernacula become weathered and are difficult to see. In late January and February, the beginning of feeding activity is evidenced by bright-yellow or cinnamon-colored particles of bark in the crotches of the young wood. The larvae break out of their silken tubes and begin to extend their burrows, throwing up tiny piles of frass loosely joined by strands of silk. Another molt usually occurs at this time. The majority of the larvae which migrate to the buds appear to be the third instar, and nearly all are the same size. Emergence from dormancy extends over a period of about a month. Thus, the earliest emerged larvae are mature by the time all the hibernacula are empty.

Parasite larval activity continues during the winter season. This is discussed elsewhere in the bulletin (p. 31). Although there is some mortality of the newly hatched twig borer larvae before entrance is made into twigs, bark, or fruit, the amount is difficult to determine.

There is usually only one larva in each hibernaculum but, now and then, when the infestation is heavy, several larvae may be found in interconnecting tunnels in a small bark section. Only the chimneys and the dorsal portion of the tubes are covered with silk. This silk is not tough—for instance, not nearly so tough as that of the codling moth.

Large numbers of hibernating larvae are often found on young almond and peach trees which have not yet come into bearing and therefore are not yet sprayed annually. We have found as many as 80 hibernacula on a single three-year-old almond tree at Arbuckle, but the average number is many fewer. In 1942, young trees were sampled to determine the degree of variation in the infestation and parasitism. The results are presented in table 8. The variation from orchard to orchard and district to district is even greater.

The larvae often construct several tunnels before settling down to their permanent overwintering quarters. If removed, a larva quickly forms another chamber. It may be readily transplanted from peach to almond, to plum, etc. Also, both in summer and winter, we have removed larvae from the bark, and have placed them on green shoots upon which they immediately began to feed. Larvae hatched from the same group of eggs have been separated, and some have been caged on bark and the remainder on growing terminals. Those confined to the bark developed very slowly, while those feeding entirely on new growth developed to maturity in about 10 days. Larvae that have fed upon fruit and green shoots will not feed upon bark unless forced to do so—for example, under laboratory conditions. As the bark dries out, the larvae abandon it.

The number of instars varies from 4 to 5, apparently depending on the rate of growth of the larvae.

A method sometimes used for determining larval instars is the measurement of the head capsule which, according to Dyar's Law, follows a regular geometrical progression in successive instars. In his studies of *Anarsia lineatella* in 1933, G. L. Smith made such measurements of hibernating larvae on peach during January, February, and March. His unpublished tabular data are given on page 19.

In our studies, 1,189 larvae were mounted and the head widths measured.

The tabulation in table 2 (p. 20) summarizes the results and shows that the larvae found feeding (or hibernating) on the bark range from 0.1 to 0.5 millimeter in the width of head. Those larvae recovered from fruits and wilted twigs are larger, the measurements varying from 0.2 to 1.0 millimeter in the width of head. The width of the head of newly hatched larvae averages about 0.1 millimeter and that of the full-grown larvae about 0.9.

Width of head capsule in mm	Number of larvae measured
0.15–0.19	5
0.20–0.24	18
0.25–0.29	36
0.30–0.34	52
0.35–0.39	11
0.40–0.0	3
0.85–0.0	1
	126

Field observations and rearing experiments lead us to believe that there are 4 to 5 instars in the feeding larvae during the summer, and that the hibernating larvae pass through an additional instar. However, a large number of larvae should be carefully reared in order to verify completely this observation and to determine the validity of Dyar's law as it may, or may not pertain to *Anarsia lineatella.* Some individual larvae, in the summer months, first feed on bark—and actually form a hibernaculum—and later migrate to green shoots or fruit. This condition makes it additionally difficult to accurately evaluate the number and length of instars by measurements of only those feeding larvae collected in the field (table 3). Peterson and Haeussler (1928) have pointed out these features when employing similar measurements of the oriental fruit moth larva. Imms (1934, p. 195), in discussing Dyar's work, states, "The factors determining the number of ecdyses need investigation and it is at present impossible to judge how far they are phylogenetic in significance, and how far they are an expression of internal physiological processes in the species concerned."

In the spring, the emerging larvae crawl upward along the limbs and twigs seeking new growth on which to feed. The first blossoms or leaf buds encountered show a small amount of feeding injury, seldom severe. This wandering and feeding period extends from the time the buds begin to swell until the new growth is about 3 to 4 inches long. By the time wilted tips are readily found, many of the larvae have matured. This is evidenced by the empty tunnels in the dead tips. An individual larva will attack several buds or shoots before reaching maturity. The lateral buds or slower-growing shoots usually have the terminal bud eaten out by the larva. The succulent shoots are nearly always attacked from the tip downward for a distance of about ½ to 2 inches.

When emerging from the tip, the larva either backs out or chews a hole to the outside at a point where the new growth has begun to harden. The flow of sap induced by feeding sometimes causes the larva to abandon its attempt to burrow in. When feeding in the blossoms, the larva commonly chews through the calyx and consumes the ovary. Only the most succulent growth is attacked, and the larval activity progresses upward and outward with the growth of the host. The variation in the number of wilted twigs—as well as the injured meats—among varieties of almonds (table 4) is apparently caused by the rate of growth and relative number of succulent shoots present.

After reaching full growth, the larva migrates downward to the larger limbs and trunk as it seeks a suitable place in which to pupate. This prepupal period or wandering stage lasts 2 or 3 days. After finding a suitable crack, pruning scar, section of curled bark, or similar spot, the larva spins a loose, grayish-white web, and transforms into the pupal stage beneath it.

The feeding larvae of the summer generations appear to prefer the fruit to the

Table 2: NUMBER OF PEACH TWIG BORER LARVAE EXHIBITING VARIOUS HEAD CAPSULE MEASUREMENTS THROUGHOUT THE YEAR*

(Width in millimeters)

Month	Number of larvae classified according to head capsule measurement																	
	On or under bark									On green shoots and fruit								
	.108–.200	.201–.300	.301–.400	.401–.500	.501–.600	.601–.700	.701–.800	.801–.900	.901–1.000	.108–.200	.201–.300	.301 –.400	.401–.500	.501–.600	.601–.700	.701–.800	.801–.900	.901–1.000
May	7	31	2	...	...	...	...	...	...	...	...	...	...	3	1	10	22	2
Late May and June	63	174	64	3	...	...	...	...	...	...	4	3	21	48	6	1	52	4
July†	...	...	...	...	...	...	...	...	...	...	...	1	...	3	...	10	22	2
July and August	42	154	173	2	1	...	...	...	...	...	...	...	9	4	...	2	7	...
September	3	22	20	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
October	16	49	46	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...
November	...	4	6	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...
February	...	18	36	12	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Totals	131	452	347	20	2	...	...	...	...	...	4	4	30	58	7	23	103	8

* Blank squares mean that none of the specimens measured fell into these groups.
† No bark samples available in July.

twigs, particularly if given a choice. On young, nonbearing trees the feeding habits of the larvae are the same as those of the overwintering brood in the spring. Terminal buds are eaten out and the tips mined. The rate of growth is more rapid, seek more suitable food. In large peach orchards in which the ground is well shaded, larvae will mature and pupate in and on fallen fruit.

Jones (1935) wrote that "the fruit feeding larvae rarely attack more than one fruit or feed in more than one spot upon a single peach. Several larvae may attack one fruit; in 1931 as many as 15 were counted in one peach." The larvae in fruit typically mine cavities just beneath the skin; occasionally they tunnel into the flesh. Jones found that on 350 infested peaches there were 378 points of entry. Of these, 41 per cent were near the stem, 34.4 per cent on the side, 19 per cent in the seam, and 5.6 per cent in split pits.

Table 3: SEASONAL DEVELOPMENT OF LARVAE IN HIBERNACULA ON ALMOND
Arbuckle, California

Date	Number of hibernacula	Number of first instar larvae	Number of second instar larvae	Total
1940:				
May 28*	..	..	..	..
June 19	50	25	25	50
July 8	39	2	20	22
August 13	76	52	10	62
September 13	75	21	37	58
1941:				
April 10	48	0	0	0
May 20	22	13	0	13
May 29	104	54	12	66
June 10	91	50	9	59
July 2	113	35	62	97
August 4	108	20	45	65
September 3	122	34	23	57
October 3	115	7	23	30
November 4	106	1	24	25
December 1	103	0	14	14
1942:				
January 2	71	0	6	6
February 4	84	0	7	7
February 17	92	0	7	7
March 2	72	0	2	2
March 16	94	0	0	0

* Many new hibernacula—all first instar larvae.

and all sizes of larvae are commonly seen on the same tree.

Twig borer larvae rarely attack overripe fruit, and they do not feed in rotten, watery, or mushy portions of fruit because they readily become trapped and drowned in such media. Infested fruit often drops to the ground with feeding larvae inside. If such fruit lies in the sun or becomes hot, the larvae die or quickly leave and attempt to crawl up the trees or

In comparison with the hibernating larvae, there is very little evident parasitism of the feeding larvae. Various predatory insects and birds consume a few larvae, but their effect on the population appears insignificant.

Habits of Pupa. On young trees, the pupae are concentrated on the trunk from the ground up to the crotch and under the rougher bark of the main forks (fig. 11). The description, time of pupation, and the length of this stage have been discussed elsewhere. Pupae are readily distributed in the corners and cracks of lug boxes where many mature larvae have pupated after crawling out of picked fruit. Observing that pupae often collect under tree protectors in young orchards (fig. 11), we obtained data on their abundance by removing the tree protectors on four adjacent rows and recording the numbers. These trees were the same unsprayed ones used in table 4. The results are shown in table 5 (see also table 16).

Additional data on abundance were secured by placing untreated corrugated cardboard bands on 24 trees from May 28 to June 10, 1940. These attracted 98 larvae for pupation, or an average of 4.0 per tree. The per cent of natural mortality of this collection was 20.5. No parasites were present.

Table 4: WILTED TWIG COUNTS OF PEACH TWIG BORER ON ADJACENT ROWS OF THREE-YEAR-OLD ALMOND, ARBUCKLE, CALIFORNIA, 1940

Variety	Total number trees	Number trees infested			Number newly wilted twigs			Average number wilted twigs per tree		
		May 13	June 10	July 16	May 13	June 10	July 16	May 13	June 10	July 16
Texas	52	35	47	35	197	186	72	3.78	3.58	1.38
Ne Plus	52	37	48	23	192	137	35	3.69	2.65	.67
Nonpareil	52	51	18	8	546	23	13	10.50	.45	.25
Peerless	52	48	30	10	568	49	12	10.92	.95	.23

Table 5: PEACH TWIG BORER PUPAE FOUND UNDER TREE PROTECTORS ON THREE-YEAR-OLD ALMOND, ARBUCKLE, CALIFORNIA

May 7, 1940

Variety	Number trees	Number trees infested	Total number pupae	Number pupae alive	Per cent mortality	Average number pupae per tree
Peerless	52	32	187	56	31.0	3.58
Nonpareil	52	40	174	89	51.1	3.34
Ne Plus	52	26	96	30	31.2	1.85
Texas	52	20	68	26	38.2	1.30

Seasonal Cycle. The seasonal cycle of this insect (table 6) is the same, no matter what the host is, but the number of annual generations varies. The period of seasonal activity is longer on peaches than on apricots, plums, and almonds and, consequently, there are one or two more annual generations in peach-growing districts. This difference is more clear-cut in areas where only peaches, apricots, or almonds are grown. In districts where many types of orchards are within close proximity, the number and peaks of broods are less distinct.

The annual cycle of the twig borer can be illustrated by using the two extreme

Table 6: SEASONAL CYCLE OF THE PEACH TWIG BORER IN THE SACRAMENTO VALLEY, CALIFORNIA

	On peach		On almond						
	1932	1933	1938	1939	1940	1941	1942	1946	1947
	(F. H. Wymore)	(Jones and Smith)							
1. First larvae feeding under bark	Feb. 20	Mar. 16	Mar. 4	Mar. 6	Feb. 16	Jan. 20	Jan. 26	Feb. 15	Feb. 18
2. First wilted shoots	....	....	Mar. 19	Mar. 20	Mar. 7	Mar. 7	Mar. 16	Mar. 15	Mar. 11
3. First pupa	Mar. 29	Apr. 6	Apr. 13	Apr. 5	Mar. 22	Mar. 28	Apr. 4	Apr. 18	Mar. 25
4. First moths	Apr. 15	Apr. 18	Apr. 26	Apr. 14	May 7	Apr. 21	May 6	May 11	Apr. 25
5. First larvae of May brood	May 4	May 5	May 5	May 2	May 13	May 9	May 22	May 21	May 5
6. Pupa of first summer brood	June 3	June 7	June 22	May 22	May 28	June 10	June 11	June 18	May 22
7. First moths of midsummer brood	....	June 15	....	May 31	June 10	June 22	July 2	July 6	....
8. First larvae of midsummer brood	June 24	....	....	July 1	July 8	July 2	July 7	July 16	July 1
9. Larvae feeding on nuts	....	....	....	....	July 8–26	July 2–21	July 17–Aug. 12	July 16–Aug. 27	July 15
10. All seasonal activity completed	Oct. 18	....	Sept. 7	Sept. 11	Sept. 13	Sept. 3	Sept. 19	Sept. 30	Sept. 1

cases—on apricots and on late cling peaches, such as Levi or Phillips. On apricots the overwintering larvae begin feeding under the bark in late February or as soon as the trees break dormancy. These larvae complete their maturity at a rather slow rate during the cool weather or early spring, and may be found tunneling into the twigs during March and early April. Pupation lasts 10 to 15 days. The mating and egg-laying period of the moth is about 2 weeks. The egg stage at this season lasts 7 or 8 days. In early May the larvae of the first brood appear in small numbers. Stragglers of this brood may be found even a month later. By the time the second generation of the season hatches (early July), the apricots are harvested,[3] and the larvae distribute themselves over the trees as they feed on the new growth. Some of the larvae feed under the bark, and do not seem to develop beyond the second instar. In August it is difficult to find any larvae feeding on the new growth except occasionally in young orchards. Thus, since a very small third generation occurs on apricots, wilted shoots are very rarely seen at this time of year. However, more than 90 per cent of the larvae are to be found in the crotches feeding under the bark. From the above discussion, it can be seen that a large seasonal build-up does not occur on apricots. Hibernacula are found readily only on young apricot plantings.

In contrasting the annual cycle of the pest on peaches with that on apricots we note some differences. Spring activity of the twig borer begins somewhat later on peaches than on almonds and apricots, but is fundamentally the same. The May brood also appears a little later. In years when cool weather causes very slow development, the May brood does not reach a peak of activity until the first of June. In most peach-growing districts in the upper San Joaquin and Sacramento valleys, the period May 15 to 20 will find this brood active. The first summer brood, or second generation, appears in early July at the time the Tuscan variety is being harvested. From this time on, it is difficult to distinguish clear-cut broods. All stages can be found up to the first of September. The movement of moths to later-maturing varieties of peaches, as discussed elsewhere, contributes to a build-up in the total population by the harvest peak of midsummer varieties in August. In districts of large acreages of the Phillips variety, the seasonal peak of these overlapping summer broods is not reached until early September. It may be said, therefore, that there are three definite broods—in May, July, and late August—with a partial fourth brood in early September in some districts.

It appears that the relative proportion of each brood tunneling under the bark increases throughout the season until late summer when, after the last varieties of fruit are harvested, all larvae form hibernacula. The annual cycle of the hibernacula is illustrated in table 7.

The seasonal cycle on nectarines, plums, and almonds is very similar to that on peaches—two definite broods, May and July, with a partial third. On almonds, the third brood extends over a period of 4 or 5 weeks or until the last hard-shelled varieties are harvested. On these hosts, a much larger percentage of the newly hatched larvae of the July brood—the second generation—and nearly all of the August brood feed entirely under the bark (table 3). These larvae do not mature until the following spring. Occasional mature larvae may be found during warm days in September on any of the host crops. These individuals constitute, technically, a fourth generation.

PARASITES

Ever since the peach twig borer was first studied by Marlatt and his associates, by Clarke, and later workers in California, parasites have been known to play

[3] The peak of the apricot harvest (at Winters, California) is May 25 to 28 in an average year.

an important part in its abundance. In 1931, *Paralitomastix pyralidis* (Ashm.) was introduced into this state and liberated in both southern and northern California. Although now established in California, it is rarely seen. It attacks the twig borer egg, but eventually kills the host in the larval stage. *P. pyralidis* is polyembryonic. Additional information on this parasite is given under the section on control. Whether or not the remainder of the parasites listed are all native enemies is not known. The parasites and predators include wasp and fly parasites of the larva. In the hibernaculum, the larva is attacked by 2 species of wasps, a thrips, 2 species of beetles, and the grain or itch mite, as listed in the following tabulation.

KNOWN PARASITES AND PREDATORS OF THE PEACH TWIG BORER, *Anarsia lineatella* Zell.

Hymenoptera

Ichneumonidae

Ephialtes sanguinipes **(Cress.)**—most common in 1932–1933 from pupa of host.
Itoplectis obesus **Cush.**—from pupa.
Aenoplex phryganidiae **Ashm.**—from pupa (may be secondary).
Dicaelotus pacificus **Ashm.**—from pupa.

Eulophidae

Secodella cushmani **Crawf.**—on larva in hibernacula.

Pteromalidae

Dibrachys boucheanus **(Ratz.)**—stage of host reared from unknown.
Pseudomicromelus deplanatus **(Nees)**—from pupa.

Eupelmidae

Tineobius californicus **Ashm.**—from pupa supposedly.
Eupelmus **sp.** (near *brevicauda* **Crawf.**)—from pupa.

Chalcididae

Spilochalis torvina **(Cress.)**—from pupa (quite common).

Braconidae

Microbracon mellitor **(Say)**—stage of host attacked unknown.
Microbracon gelechiae **(Ashm.)**—attacks twig borer larva.

Encyrtidae

Paralitomastix pyralidis **(Ashm.)**—host egg parasitized and adult parasites hatch from host larva. Introduced from France in 1931.
Copidosoma variegatum **Howard** occurs in New York but not in California.

Elasmidae

Elamus setosiscutellatus **(Crawford)**—from host larva.

Tetrastichidae

Hyperteles lividus **(Ashm.)**—on larva in hibernacula.

Diptera

Tachinidae

Anachaetopsis tortricis **Coq.**—from host pupa.

Thysanoptera

Phlaeothripidae

Leptothrips mali **(Fitch)**—on eggs and small larvae chiefly in hibernacula.

Coleopoptera

Anthicidae

Notoxus constrictus **Casey**—adult beetle predacious on pupae and larvae in hibernacula on almonds. Observed at Chico only.

Cleridae

Hydnocera scabia **LeConte**—Larva predacious on hibernacula observed at Chico only.

Arachnida

Tarsonemidae

Pediculoides ventricosus **(Newport)**—predacious on larva in hibernacula. Especially abundant in the Vacaville district and westward.

Our attention has recently been called to the parasite host catalogue prepared by W. R. Thompson (1944). This author lists the following additional parasites of *Anarsia lineatella:*

Apanteles anarsiae **Faure** and **Alabouvette (Hym. Braconid)**
Apanteles emarginatus **Nees (Hym. Braconid)**
Apanteles xanthostigmus **Hal (Hym. Braconid)**
Dibrachys cavus **Walk. (Hym. Pteromalid)**
Elasmus flabellatus **Fonsc. (Hym. Elasmid)**
Euderus **sp. (Hym. Eulophid)**
Hemiteles incisus **Bridgm. (Hym. Ichenumonid)**
Paralitomastix varicornis **Nees (Hym. Encyrtid)**
Perisierola gallicola **Kieff (Hym. Bethylid)**
Phygadeuon rusticatus **Wesm. (Hym. Ichenumonid)**
Spilochalcis side **Walk. (Hym. Chalcid)**

In the period of years that the writer has studied this pest, many observations, counts, and miscellaneous data have been gathered on parasitism, particularly on the hibernaculum stage. It has been hoped that some basis could be established for predicting the relative numbers of overwintering larvae and the subsequent infestation the following spring. This study, however, has brought out a number of facts not previously known, and shows that, as yet, we do not understand the entire picture of natural parasitism.

During the period of active feeding in the spring and summer, it is very difficult to obtain data on the degree of parasitism on the eggs, feeding larvae, and pupae. Larvae may be collected from wilted shoots and infested fruit. This process is slow and yields very little data of value. Many of the parasites thus collected hatch from the pupae. The collecting of pupae in sufficient numbers to be indicative is made most difficult by the insect's habit of secreting the pupa in the rough bark. On young trees, however, strips of cardboard, cloth, or tree protectors wrapped around the trunk will result in a concentration of pupae. The eggs of the twig borer are most difficult to find in the field. In addition to the parasite *P. pyralidis*, adult and larval thrips (*Leptothrips mali*) have been seen feeding on the eggs. There are no known parasites of the adult moth.

On the other hand, during the greater part of the year, hibernacula can be found on the young wood (table 7). It is in this stage exclusively that overwintering takes place. Therefore, it has been possible to make a detailed study of the parasites attacking this stage, and their effect on the seasonal abundance of the host insect. The degree of mortality of the inactive

Table 7: ANNUAL CYCLE OF HIBERNACULA ON ALMOND
Arbuckle, California

Date	Number samples	Alive	Dead	Empty	Parasitized	Per cent mortality*
1940:						
June 19	50	50	0	0	0	0
July 8	39	22	0	17	0	0
August 13	76	62	0	14	0	0
September 13	75	58	0	15	1	1.6
October 16	133	75	17	20	21	33.0
November 14	133	40	26	44	23	55.0
December 14	106	10	30	51	15	81.0
1941:						
January 9	106	15	16	50	25	73.0
February 12	104	4	2	90	8	71.0
February 24	116	4	0	102	10	71.0
March 7	97	6	8	75	8	72.0
March 17	105	0	2	99	4	100.0
April 10	48	0	3	43	2	100.0
May 20	22	13	0	9	0	0.0
May 29	104	66	8	25	0	0.0
June 10	91	59	3	28	1	1.5
July 2	113	97	3	11	2	4.8
August 4	108	65	4	33	6	13.3
September 3	122	57	11	44	10	26.9
October 3	115	30	12	48	25	55.2
November 4	106	25	10	49	22	56.1
December 1	103	14	9	63	17	65.0
1942:						
January 2	71	6	5	48	12	73.3
February 4	84	7	5	48	24	80.5
February 17	92	7	1	62	22	76.6
March 2	72	2	0	64	6	75.0
March 16	94	0	0	89	5	100.0
April 16	42	0	0	42	0	0.0
May 22	None present					
June 5	49	26	0	23	0	0.0
June 11	39	14	1	23	0	6.6
June 24	73	49	1	23	0	2.0
July 7	93	52	5	33	3	13.3
August 3	99	49	5	43	2	12.5
September 19	104	66	6	30	2	10.8
1946:						
March 15	65	4	1	57	3	50.0
April 24	23	0	0	23	0	0.0
May 27	42	37	0	6	0	0.0
June 29	121	77	9	31	4	14.4
July 29	108	46	5	45	12	28.5
August 27	87	41	4	41	1	10.8
September 30	84	55	0	29	0	0.0
October 28	95	66	5	23	1	8.3
November 29	104	69	3	30	2	6.7
December 27	166	84	8	54	20	25.0

* The per cent mortality was determined by subtracting the number of empty hibernacula from the number of samples; the number of dead and parasitized were added and this figure was divided by the number of hibernacula containing live larvae plus those dead and parasitized. For example, on December 27, 1946, of the 166 samples collected, 54 were empty. 166–54=112. There were 28 dead and parasitized—28/112=25.0 per cent mortality.

larvae is negligible during May, June, and July, but in the fall it rises sharply and by February usually reaches the seasonal maximum. If bark samples are taken in late January and February to determine the degree of parasitism, a general indication is had of the potential infestation for the season, at least in the orchard sampled.

Neither Clarke nor Duruz found this parasite, probably because the major portion of their work was conducted in a different area from that of Ehrhorn. The writer has noted a marked increase in the abundance of this mite progressively from Winters to Vacaville to Fairfield. Also, there appears to be some correlation between the type and amount of covercrop and subsequent mulch in the orchard, and the abundance of the mite. Herms (1939) has reviewed the life history of this predator.

Table 8: PARASITISM OF HIBERNACULA* ON ALMOND, ARBUCKLE, CALIFORNIA

February 4, 1942

Row number	Number hibernacula	Alive	Dead	Empty	Wasps†			Parasites				Per cent mortality
					Larva	Pupa	Adult	Thrips	Mites	Beetles	Total	
1	48	1	5	37	..	2	2	..	1	..	5	90.9
2	42	1	3	34	2	1	..	..	..	1	4	87.4
3	57	2	..	44	6	3	..	..	1	..	10	84.6
4	50	6	1	36	1	5	1	..	..	..	7	57.1
5	47	2	2	31	3	5	2	..	1	1	12	87.5
6	52	1	2	39	4	2	4	..	..	..	10	92.3
7	44	2	4	31	1	6	..	..	..	..	7	84.6
8	40	6	2	26	1	1	..	3	..	1	6	57.1
Total	380	21	19	278	18	25	9	3	3	3	61	80.1

* Variation of population of hibernacula and parasites in one orchard of four-year-old unsprayed almond trees, adjacent rows. All visible hibernacula removed from 5 trees in each row.
† Hyperteles lividus (Ashm.).

In conducting this study it was extremely difficult to find sufficient hibernacula on apricots, prunes, and plums to compile any data, chiefly because of the light infestations on the young trees and the unusually rough bark on the older trees. Therefore, the majority of the hibernacula was obtained from peach and almond. A continuous record of parasitism in an unsprayed almond orchard at Arbuckle was obtained from June, 1940, to January, 1947.[4] These data are given in table 7.

The grain or itch mite, *Pediculoides ventricosus* (Newport), was recognized by Marlatt (1898) as destroying as high as 95 per cent of the overwintering larvae.

[4] Exclusive of November, 1942, to February, 1946, when the writer was with the Armed Forces of World War II.

The predacious thrips, *Leptothrips mali* (Fitch), frequently becomes sufficiently abundant to aid somewhat in reducing the peach twig borer but holds only a poor third place in abundance in the hibernacula. The details of its habits have been published by the writer (Bailey, 1940).

The data in table 7 show very clearly the seasonal trend which reoccurs in the same order each year, at least for the principal hymenopterous parasite here involved, namely, *Hyperteles lividus*. The seasonal peak of mortality is reached in the late winter. In March and April, or at the time all of the surviving host larvae have emerged and have migrated to the

Table 9: PARASITISM OF HIBERNACULA* ON ALMOND, ARBUCKLE, CALIFORNIA
January, 1942

Number samples	Alive	Dead	Empty	Wasps†			Parasites				Per cent mortality
				Larva	Pupa	Adult	Thrips	Mites	Beetles	Total	
88	24	11	41	3	4	..	2	3	..	12	49
88	26	10	32	14	..	..	2	4	..	20	53
116	53	14	35	5	7	..	..	2	..	14	34
106	53	8	38	4	..	..	..	3	..	7	22
91	21	15	45	2	2	..	..	3	1	10	54
104	21	17	44	11	..	..	4	2	..	17	56
76	26	6	27	6	..	..	8	3	..	17	46
126	16	30	57	8	..	2	9	3	1	23	76
59	14	15	23	3	..	..	4	..	..	7	65
129	58	9	47	2	..	..	1	12	..	15	29
68	21	13	21	4	..	..	1	8	..	13	55
80	22	17	28	9	..	..	3	1	..	13	38
111	35	16	52	3	..	..	2	2	1	8	41
Total	390	181	490	74	13	2	36	46	3	176	47

* Variation of parasite population of hibernacula in unsprayed portions of the spray plots. All visible hibernacula removed.
† Hyperteles lividus (Ashm.).

Table 10: PARASITISM OF HIBERNACULA* ON ALMOND, ARBUCKLE, CALIFORNIA
1940–1942

Date	Number samples unsprayed	Alive	Dead	Empty	Wasps†			Parasites				Per cent mortality
					Larva	Pupa	Adult	Thrips	Mites	Beetles	Total	
1940:												
Jan.	100	70	4	..	..	..	..	..	..	..	26	30
Dec.	81	46	10	23	2	..	..	..	..	..	2	20
1941:												
Jan.	500	257	18	219	4	1	..	..	..	..	7	8
Feb.	331	147	39	129	8	..	..	..	1	7	16	27
Dec.	328	120	31	94	49	1	2	7	12	2	73	43
1942:												
Jan.	1,242	390	181	490	74	13	2	36	46	3	176	47
Feb.	304	76	26	147	19	18	..	..	18	..	55	51

* In checks of the spray plots. All visible hibernacula removed.
† Hyperteles lividus (Ashm.).

Table 11: PARASITISM OF HIBERNACULA ON ALMOND

Winters, California, 1946

Date	Number samples*	Alive	Dead	Empty	Wasps†			Parasites				Per cent mortality
					Larva	Pupa	Adult	Thrips	Mites	Beetles	Total	
1946:												
February 28	115	52	10	41	3	1	..	..	8	..	12	29.8
March 30	77	2	1	70	1	1	..	2	..	..	4	71.4
April 18	50	0	0	49	1	..	..	..	..	..	1	100.0
May 21	26	20	0	6	..	..	..	..	..	..	0	0.0
June 24	120	34	24	40	4	14	4	..	..	..	22	57.5
July 16	67	30	5	24	4	3	..	..	1	..	8	30.2
August 23	107	18	18	56	4	10	1	..	..	..	15	64.7
September 28	67	21	9	32	..	..	5	..	..	..	5	40.0
October 30	80	17	3	44	8	3	3	2	..	..	16	52.7
December 18	72	7	4	47	7	..	1	6	..	..	14	72.0

* 100 bark samples removed, some of which contained no hibernacula, except in April and May, at which time all visible hibernacula were removed. Only one orchard sampled.
† Hyperteles lividus (Ashm.).

new terminals, all of the remaining hibernacula are occupied by dead larvae or parasites. Usually in May some new hibernacula begin to appear, and from this time on the parasites find enough small host larvae to maintain themselves. The increase in the number of first instar larva forming hibernacula in August and September temporarily reduces the proportionate number of parasites. During the fall, parasite activity increases as the host's population becomes stabilized.

The normal variation in the number, type, and per cent of parasitism in a young unsprayed almond orchard on adjacent rows is shown in table 8. The average per cent mortality of the overwintering larvae on February 4, 1942, was 80.1, but the extreme range of the 8 samples was from 57.1 to 92.3 per cent on adjacent rows.

During the period 1940–1942, 7 widely scattered orchards were sampled in January to obtain comparative data on parasitism. The data are given in table 15, with an indication of the relative degree of injury the same season. Here again there is exhibited great variation. These data were based on one sample only—about 100 hibernacula—from a selected orchard of almond or peach in each district. When compared with the relative degree of injury during the following summer, little correlation can be seen.

In order to determine a possible variation in the type of seasonal cycle or in the other habits of the parasites of the hibernaculum on hosts other than almond, monthly records likewise were kept on a young peach orchard. This orchard, located at Tudor in Sutter County, received a normal spray schedule. The data are presented in table 12. The seasonal trend shown is the same as that on almonds, and the same parasites are involved.

During the course of the dormant control studies, complete records were kept on the number and type of parasites (tables 9 and 10), and these present additional facts of value in this phase of the study. Tables 9, 13, and 14 illustrate the nature of the parasitism on plums, nectarines, and almonds in January, 1942. These data show that the per cent of natural parasitism varies greatly, not only on almonds but also on plums and nectarines. Here again, the hymenopterous parasite, *Hyperteles lividus,* is the most important, a fact also true in 1921–1922 when Duruz reported 70 to 90 per cent parasitism.

Hyperteles lividus (illustrated by Duruz, fig. 10, page 436, 1923) has definitely been the most effective parasite in recent years in the Sacramento and upper San Joaquin valleys. It is generally more effective in the southern portion of the Sacramento Valley (compare tables 7 and 11), the San Joaquin Valley, and toward the coast than in the upper Sacramento Valley. This condition may be the result of higher minimum winter temperatures in these areas. The eggs are deposited on the body of the twig borer larva in the hibernacula. The host larva appears to be stung and paralyzed at this time since, when removed from the bark chamber, it lacks the ability to crawl. The parasite larva feeds externally and, during the summer, matures in about 3 weeks. Its pupal stage lasts from 7 to 10 days. During the fall and winter there is one prolonged generation of the parasite. The larva and pupa of this parasite are, in turn, attacked by the predators mentioned above. As shown in tables 8 to 14, inclusive a few pupae and adults are found during the winter, but the majority of the parasites passes the winter in the larval stage and emerges in the early spring. The parasite larva is legless, attacks only one host larva, and does not migrate to adjoining hibernacula. As previously mentioned, nearly 100 per cent of the wasp larvae found in the hibernacula during this period have been *H. lividus. Secodella cushmani* Crawf. has been recorded as common by Keifer and Jones (1933) and

Table 12: PARASITISM OF HIBERNACULA ON PEACH

Tudor, California, 1940–1942

Date	Number samples*	Alive	Dead	Empty	Wasps†			Parasites				Per cent mortality
					Larva	Pupa	Adult	Thrips	Mites	Beetles	Total	
1940:												
September 27	115	67	15	24	‡	‡	‡	‡	‡	‡	9	26
October 25	171	39	19	87	‡	‡	‡	‡	‡	‡	26	53
November 20	144	23	15	70	27	2	3	3	1	..	36	68
December 19	138	12	14	85	21	1	1	..	4	..	27	77
1941:												
January 30	137	2	5	125	5	..	..	..	..	..	5	41
February 24	106	5	0	102	..	..	1	..	..	..	1	25
July 15	113	29	19	47	1	3	..	4	..	..	8	40
August 16	77	18	11	47	..	1	..	..	..	..	1	40
September 15	113	79	7	26	..	..	1	..	..	..	1	9
October 18	106	73	10	20	..	..	..	2	1	..	3	15
November 18	116	71	11	28	5	..	1	..	..	..	6	19
December 16	105	42	18	39	3	..	3	2	..	..	8	39
1942:												
January 15	80	32	8	34	2	2	..	2	..	..	6	30
February 17	87	8	4	66	1	5	..	2	1	..	9	61
March 18	94	2	5	80	..	5	2	..	..	..	7	85
April 16	46	0	2	44	..	..	..	..	..	..	0	100
May	§	§										
June 5	38	6	7	25	..	..	..	..	..	..	0	53
July 2	43	29	0	14	..	..	..	..	..	..	0	0

* Samples obtained in same manner as in Table 11. In April, June, and July, 1942, all visible hibernacula removed. Only one orchard sampled.
† Hyperteles lividus (Ashm.).
‡ Type of parasite not recorded.
§ None present.

Table 13: PARASITISM OF HIBERNACULA ON TRAGEDY PLUMS
Marysville, California
January, 1942

Number samples* (unsprayed)	Alive	Dead	Empty	Wasps†			Parasites				Per cent mortality
				Larva	Pupa	Adult	Thrips	Mites	Beetles	Total	
92........	74	3	15	..	..	..	..	..	..	..	3
87........	53	4	27	1	..	..	1	1	..	3	11
97........	69	6	22	..	..	..	..	..	..	..	8
Total: 276........	196	13	64	1	..	..	1	1	..	3	7
Santa Rosa plums 101........	50	18	22	3	..	..	5	2	..	10	35

* 100 bark samples removed from each plot.
† Hyperteles lividus (Ashm.).

Table 14: PARASITISM OF HIBERNACULA ON NECTARINES
Marysville, California
January, 1942

Number samples* (unsprayed)	Alive	Dead	Empty	Wasps†			Parasites				Per cent mortality
				Larva	Pupa	Adult	Thrips	Mites	Beetles	Total	
95........	23	14	29	23	2	1	1	2	..	29	65
76........	32	10	21	11	..	..	..	2	..	13	41
Total 171........	55	24	50	34	2	1	1	4	..	42	54

* Samples obtained as in Table 13.
† Hyperteles lividus (Ashm.).

Table 15: PER CENT OF PEACH TWIG BORER PARASITISM FOR THE MONTH OF JANUARY IN VARIOUS FRUIT-GROWING DISTRICTS
1940-1942

District	1940 Moderate infestation	1941 Bad infestation on almonds	1942 Moderate to light injury	Average
	Per cent	Per cent	Per cent	Per cent
Chico..................	..	43	61	52
Gridley................	..	97	83	90
Tudor..................	94	41	30	55
Arbuckle...............	33	73	73	59
Winters................	90*	97	82	89
Vacaville..............	93	61	69	76
Manteca................	98	55	65	72
Average................	81.6	66.7	66	

* Not the same orchard as reported in 1941 and 1942. All samples (100 from adjacent trees) were taken from the same orchard each year.

Basinger (1935), and it is possible that some of the larvae recorded may be this species, but all the adults captured or reared proved to be *H. lividus.*

CONTROL

Control methods against the peach twig borer may be classified as cultural, biological, and chemical.

Cultural Methods. Destroying fallen fruit, sterilizing lug boxes, and burning the prunings are orchard practices which aid in reducing this pest. In seasons of heavy infestation in peach districts, it is very desirable to destroy the infested fallen or dropped fruit of midsummer varieties to reduce the moth population which moves on to later-maturing orchards. Mackie and Jones (1931) have discussed this phase of control.

In the vicinity of loading platforms, redistribution points, and canneries, the population builds up greatly during picking season. General sanitation around these areas, as well as sterilization of lug boxes, reduces local population.

An additional method of cultural control of the overwintering larvae is the burning of prunings. In the San Joaquin Valley, in orchards on sandy soil it is a common practice to disk under the prunings. In other areas the prunings are piled and burned. In 1938 the writer collected hibernacula from peach prunings at Davis and caged them for observation. During January, February, and early March the larvae thus confined remained in their cells, but as the bark dried out they crawled away or died. To secure the best results, the prunings should be gathered up and burned as soon as possible after being cut. The proportion of the hibernacula removed by the normal pruning operation, however, is so small that it has little effect on the infestation.

Biological Methods. Biological control methods have not been very successful against the twig borer. Aside from the established, natural parasites—discussed in the section on parasites—either introduced with the twig borer into California, or occurring on other hosts that have adapted themselves to *Anarsia lineatella,* there is one parasite which deserves special mention. This is the parasite, *Paralitomastix pyralidis* (Ashm.). Basinger (1935) has reported on this introduced parasite.

In the summer of 1932, A. J. Basinger and F. H. Wymore made liberations of this parasite in Yuba City. Keifer and Jones (1933) reported on the parasites collected in this area in 1932 and the first half of 1933 and did not find *P. pyralidis.* However, it has been established, and has actually spread to the north and west since its liberation in northern California. The writer has found twig borer larvae attacked by this parasite on three occasions: May 3, 1940, at Chico; May 7, 1940, at Arbuckle; and June 10, 1941, at Arbuckle. In each instance the host plant was almond.

It can be concluded that if in fourteen years this parasite has not become more abundant than is indicated above, it will not play an important part in the control of its host insect.

The two most important enemies are the predacious mite, *Pediculoides ventricosus* and the parasite *Hyperteles lividus,* both feeding on the small larvae in the hibernacula. No attempts have been made to encourage, increase, or liberate these parasites. Additional data on the occurrence, biology, and seasonal cycle of these parasites, as well as others, are given in another section.

Chemical Method—by Banding. To our knowledge, no previous attempts to explore the possibilities of control of the twig borer by banding have been made. In 1940 a heavily infested three-year-old almond orchard at Arbuckle was selected for a test with corrugated paper bands treated with beta naphthol, such as are used for the codling moth. Untreated bands were used as a check. Since the most concentrated and uniform time of pupation is early in June, the bands were

placed on the trunk, just below the fork on May 28, or as the larvae began to mature. The bands were removed June 10 when the first moths began to emerge. The moths were reared in the laboratory, and the data were compiled as indicated in table 16.

Since less than half as many larvae pupated in the treated than in the untreated bands, we infer that the beta naphthol has a repellent action on the mature larvae. The actual kill was surprisingly high by this method which is frequently used on apples as a supplementary means of controlling the codling moth. The method, however, would not be effective on large almond trees which have innumerable roughened areas on the trunks and larger limbs where the larvae pupate.

Table 16: RESULTS OF EXPERIMENTAL CONTROL OF PUPAE BY BETA NAPHTHOL TREE BANDS

Arbuckle, California, 1940

Number trees banded	Average number pupae caught per band	Total number of pupae	Dead in bands	Live moths emerged	Per cent natural mortality	Per cent control by treated bands
22 treated	1.8	40	38 pupae 9 moths 14 larvae	2	....	93.7
24 untreated	4.0	98	12 pupae 8 moths 0 larvae	78	20.5	....

Insecticidal Methods. Periodically, as outbreaks of the pest have occurred, the newer insecticides have been tested in order to find more effective and cheaper methods. For those readers who wish to review early experimental work and control suggestions on this pest, we point out the reports of Craw (1894), Marlatt (1898), Clarke (1902), Duruz (1923), and Plank (1936).

G. L. Smith conducted some tests during February and March, 1933, at Yuba City, California, on sucker shoots of peach heavily infested with hibernacula. Smith has kindly made his unpublished notes available to us, and we cite below various data from this source. The oils, 60 neutral, 100 filtered pale, 70 filtered pale, one of 140 viscosity, and kerosene, were applied at full strength and then with 5 per cent pyridine, 5 per cent creosote, 5 per cent toluidine, and 5 per cent "selocide." Kerosene and 70 filtered pale were used also as a carrier of 5 per cent hexachlorobenzine, 5 per cent alpha-naphtholamine, beta naphthol and PDB, as well as 0.5 per cent pyrethrum and "Nicolite" which were used in kerosene and the 60 neutral pale. In studying the data on the 45 combinations which Smith applied, we note that of the formulas giving more than 85 per cent kill, nearly all, as might be expected, showed injury to buds and bark. Those combinations that did not result in injury to the shoots were as follows:

Date applied	Formula*	Per cent mortality of larvae
2/20	60 neutral pale 5 per cent creosote	100.0
2/27	60 neutral pale, 0.5 per cent "selocide"	90.1
3/10	Water, 9 parts, "Petrotine" 1 part, 2½ per cent "Nicolite"	100.0

* Materials within quotes not in general use at present time.

Smith states that the oils 100 and 70 filtered pale, and the 140 vis. oil gave the greatest penetration into the hibernacula and concludes that "so few hibernacula have been examined that no definite statements can be made on the toxic effects and of the effects on the peach." Smith also added that conditions varied so greatly in the district, it was not surprising that lime-sulfur was generally believed to give a good control. Under controlled conditions where accurate observations could be made, lime-sulfur gave a very poor kill. Based on observations made in many orchards in a test conducted by himself, Lawrence Jones, and Plank, G. L. Smith concluded that, in early spring, the best control from sprays was obtained when applied on trees in full bloom. Smith stated that when this early spray is omitted, the brood is so uneven by late May that, unless an ovicide is used with the basic lead arsenate, control is poor.

Control measures employed in other states have been given by Edmundson (1916) in Idaho, Lovett (1923) in Oregon, List and Newton (1936) in Colorado, and Newcomer (1941) in the Pacific Northwest.

In Michigan, *Anarsia lineatella* is found in peach orchards but has never required control measures. It also occurs throughout the southern states but is rarely injurious. The usual spray of lime-sulfur—1 gallon to 10 gallons of water—and lead arsenate—3 pounds to 100 gallons of water—is used if necessary. Neither do fruit growers in New York State have to spray for this insect. R. C. Smith, *et al.* (1943) recorded this orchard pest in Kansas as being unimportant. Recent literature from the Georgia Experiment Station indicates that the peach twig borer is of so little concern in Georgia that spraying is unnecessary.

CONTROL EXPERIMENTS, 1937–1946

Following the yearly increasing losses to almonds from 1933 to 1936 (table 1), the California Almond Growers' Exchange requested advice from the University of California. Dr. J. F. Lamiman of the Division of Entomology at Davis in 1937 and 1938 carried on control experiments at Arbuckle, which the writer took over in 1939.

Control of Feeding Larva. In collecting the data cited in table 17, a random 5 pound sample of unhulled nuts was collected from the canvas at the end of each row after knocking. This totaled about 30 pounds per plot. These nuts were hulled, cracked, and the number of wormy meats tallied. The total number of meats counted per plot of 6 rows of trees each averaged about 2,000. This method was used on all plots for the six-year period, 1937–1942 and for 1947. After two years of work the Ne Plus variety was found to be uniformly lightly infested as compared with Nonpareil. The latter variety only therefore was used in the later plots.

All applications were made with the same power sprayer and standard orchard spray equipment. The dormant sprays using dinitro compounds in a power sprayer in 1940 and 1942 were disappointing when compared with the results obtained with a knapsack sprayer in small plots of young trees in the same district. The poor control on the large trees may be partially accounted for by the fact that the rough bark absorbs a greater proportion of the oil than does the thin, smooth bark of the young trees. Too, less oil was used in comparison with the other tests listed in table 17.

A summary of the lead arsenate sprays shown in table 17 is listed in table 18.

It will be noted in table 18 that the jacket spray plus the May spray reduced the infestation only slightly below the effectiveness of the May spray alone. Therefore, the value received from the two sprays did not justify the additional expense; and the two sprays were discontinued after three years. Since the chief objective of these experiments was to pre-

Table 17: RESULTS OF SPRAY PLOTS ON SOFT-SHELLED ALMONDS
Arbuckle, California
1937–1940

Date sprayed	Stage of growth	Material	Dosage	Per cent injury to nuts: Non-pareil	Per cent injury to nuts: Ne Plus
1937					
Mar. 2	Bud opening	Basic lead arsenate	4 lbs. per 100 gals. of water	5.1	1.1
Mar. 2 May 14	Bud opening	Basic lead arsenate Basic lead arsenate	4 lbs. per 100 gals. of water 4 lbs. per 100 gals. of water	3.8	1.3
Mar. 30	Petal fall	Basic lead arsenate	4 lbs. per 100 gals. of water	5.3	0.5
Mar. 30 May 14	Petal fall	Basic lead arsenate Basic lead arsenate	4 lbs. per 100 gals. of water 4 lbs. per 100 gals. of water	3.0	1.2
Mar. 30	Petal fall	Basic lead arsenate Lime-sulfur	4 lbs. per 100 gals. of water 1½ gallons	7.0	0.9
Mar. 30 May 14		Basic lead arsenate Lime-sulfur Basic lead arsenate	4 lbs. per 100 gals. of water 1½ gallons 4 lbs. per 100 gals. of water	4.8	2.4
May 14		Basic lead arsenate	4 lbs. per 100 gals. of water	3.7	2.2
	Check			7.3	1.2
1938					
Mar. 31	Petal fall	Basic lead arsenate	4 lbs. per 100 gals. of water	20.5	0.6
Mar. 31 May 24	Petal fall	Basic lead arsenate Basic lead arsenate*	4 lbs. per 100 gals. of water 4 lbs. per 100 gals. of water	9.1	0.3
Mar. 31	Petal fall	Basic lead arsenate Lime-sulfur	4 lbs. per 100 gals. of water 1½ gallons	23.1	0.5
Mar. 31 May 24	Petal fall	Basic lead arsenate Lime-sulfur Basic lead arsenate	4 lbs. per 100 gals. of water 1½ gallons 4 lbs. per 100 gals. of water	9.8	0.5
May 24		Basic lead arsenate*	4 lbs. per 100 gals. of water	11.4	0.3
	Check			35.0	1.5

* Lime-sulfur added to late spray as entire orchard was being sprayed for red spider.
† "Vaporol" and "zinc-coposil" are proprietary concentrates, applied with a spray duster.
‡ 4.1 oz. dinitro-ortho-cyclo-hexyl-phenol (hereafter referred to as DNOCHP) per gallon of oil (100–110 vis. 70 U. R.).
§ Tri-ethanolamine salt of DNOCHP.

Table 17—Continued

Date sprayed	Stage of growth	Material	Dosage	Per cent injury to nuts	
				Non-pareil	Ne Plus
1939					
Mar. 15	Petal fall	Basic lead arsenate Casein spreader	4 lbs. per 100 gals. of water ⅓ lb.	1.9	Not counted, as infestation was negligible
Mar. 15 May 9	Petal fall	Basic lead arsenate Casein spreader Basic lead arsenate Casein spreader	4 lbs. per 100 gals. of water ⅓ lb. 4 lbs. per 100 gals. of water ⅓ lb.	1.7	
Mar. 15	Petal fall	Basic lead arsenate Casein spreader	4 lbs. per 100 gals. of water ⅓ lb.	1.8	
Mar. 15 May 9	Petal fall	Basic lead arsenate Casein spreader Basic lead arsenate Casein spreader	4 lbs. per 100 gals. of water ⅓ lb. 4 lbs. per 100 gals. of water ⅓ lb.	1.4	
May 9		Basic lead arsenate Casein spreader	4 lbs. per 100 gals. of water ⅓ lb.	1.6	
	Check			1.5	
1940					
Feb. 2	Delayed dormant	Sodium dinitro cresylate (30 per cent)	1 per cent	4.5	Not counted, as infestation was negligible
Feb. 2	Delayed dormant	DN and oil†	2 per cent	3.2	
Mar. 7	Jacket stage	Basic lead arsenate Spreader	4 lbs. per 100 gals. of water ½ lb.	2.7	
May 16		Basic lead arsenate Spreader	4 lbs. per 100 gals. of water ⅓ lb.	2.3	
May 16		Xanthone Spreader	2 lbs. to 100 gals. of water ½ lb.	1.5	
	Check			2.1	

Table 17—Continued

Date sprayed	Stage of growth	Material	Dosage	Per cent injury to nuts: Non-pareil	Per cent injury to nuts: Ne Plus
		1941			
Feb. 26	Late jacket	Basic lead arsenate Liquid adhesive	3 lbs. to 100 gals. of water ½ gal.	18.0	Not counted, as infestation was negligible
May 9		Basic lead arsenate Powdered spreader	4 lbs. to 100 gals. of water ⅓ lb.	17.9	
July 7	Hulls cracking	Basic lead arsenate Powdered spreader	4 lbs. to 100 gals. of water ½ lb.	19.3	
July 7	Hulls cracking	Rotenone powder (0.58 per cent rotenone from Cubé, other ether extractions 1.16 per cent, plus 0.06 per cent pyrethrins)	5 lbs. to 100 gals. of water	21.4	
	Check			20.8	
Feb. 7	Bud swelling	Basic lead arsenate Oil concentrate‡ Zinc-copper concentrate Water (35 gals. per acre)	10 lbs. 10 gals. 15 lbs. 10 gals.	12.7	
	Check			12.3	
		1942			
Jan. 31	Dormant	Sodium dinitro cresylate (30 per cent) Dormant oil emulsion	1:200 3 per cent	10.0	Not counted, as infestation was negligible
Jan. 31	Dormant	DN(T.E.A. salt)§ Dormant oil emulsion	1:400 3 per cent	5.9	
May 26		Basic lead arsenate Spreader	4 lbs. per 100 gals. of water ⅓ lb.	4.2	
July 17	Hulls cracking	Basic lead arsenate Liquid spreader	4 lbs. to 100 gals. of water 1 qt.	4.5	
July 17	Hulls cracking	Fixed nicotine (14 per cent nicotine sulfate)	4 lbs. to 100 gals. of water	4.9	
	Check			8.4	

Table 18: SIX-YEAR SUMMARY OF PER CENT OF INFESTED NONPAREIL ALMOND MEATS IN BASIC LEAD ARSENATE SPRAY PLOTS

Arbuckle, California

	1937	1938	1939	1940	1941	1942	Average
Check	7.3	35.0	1.5	2.1	20.8	8.4	12.5
Jacket spray only	5.3	20.5	1.8	2.7	18.0	....	9.6
May spray only	3.7	11.4	1.6	2.2	17.9	4.2	6.8
Jacket plus May spray	3.0	9.1	1.4	....	....	....	....
July spray	....	....	....	....	19.3	4.5	....

vent the midsummer brood of larvae from attacking the meats of the soft-shelled varieties, a July spray was added to the tests in 1941. As can be seen from the above figures, the results were somewhat disappointing.

In the summer of 1942 an experiment was conducted at Davis on young peach trees to determine the maximum period of effectiveness of sprays against the twig borer larvae.

During May, June, and July the sprays listed below were used; fresh larvae were caged each successive day over the growing terminals after the spray had dried.

All of the rotenone compounds listed killed the larvae by contact. The general observation was made that the period of effectiveness was largely dependent on the rate of growth of the terminal leaves to which the larvae migrate. These new leaves were without spray residue. This accounts for the variation in the effectiveness of duplicated treatments. Also, from the standpoint of practical field control, it accounts readily for the lack of control by the May spray often reported in years of heavy infestation. If there is a marked overlapping of stages at this time, a single May spray is not too effective.

Material	*Maximum period of effectiveness (days)*
Rotenone powder (about .60 per cent rotenone plus 0.06 per cent pyrethrins and 17.00 per cent petroleum oils) 5 lbs. to 100 gals.	5
Rotenone powder (about .60 per cent rotenone plus 0.06 per cent pyrethrins and 17.00 per cent petroleum oils) 5 lbs. to 100 gals.	9
Rotenone powder (about .60 per cent rotenone plus 0.06 per cent pyrethrins and 17.00 per cent petroleum oils) 5 lbs. to 100 gals.	4
Rotenone powder (about .60 per cent rotenone plus 0.06 per cent pyrethrins and 17.00 per cent petroleum oils) 2½ lbs. to 100 gals.	4
Rotenone powder (about .60 per cent rotenone plus 0.06 per cent pyrethrins and 17.00 per cent petroleum oils) 2½ lbs. to 100 gals.	2
Rotenone powder, 4 per cent, 2 lbs. to 100 gals.	9
Rotenone powder, 4 per cent, 2 lbs. to 100 gals.	6
Rotenone powder, 4 per cent, 1 lb. to 100 gals	2
Rotenone powder, 4 per cent, 1 lb. to 100 gals.	6
Rotenone liquid concentrate (5 per cent rotenone and 1 per cent dispersing oil)	2
Rotenone liquid concentrate (2.8 per cent rotenone) 1/400	0
Sodium fluoaluminate, 3 lbs. to 100 gals., ½ lb. spreader	5
Sodium fluoaluminate, 3 lbs. to 100 gals., ½ spreader, with 1 lb. sugar	8
Sodium fluoaluminate, 3 lbs. to 100 gals., ½ spreader, with 1 lb. sugar	4
Xanthone, 3 lbs. to 100 gals. ½ lb. spreader	0
Tartar emetic, 3 lbs. to 100 gals., sugar 3 lbs.	0
Liquid basic lead arsenate, 2 qts. to 100 gals.	13
Liquid basic lead arsenate, 2 qts. to 100 gals., with 4 lbs. sugar	8
Basic lead arsenate, 4 lbs. to 100 gals., ½ lb. spreader	4

In 1940, reports indicated that in the Sacramento Valley heavy worm infestations were building up on midsummer peaches. Various orchards having different treatments were checked at picking time (table 19) to determine the actual degree of injury and the relative effectiveness of the control measures locally employed. No check trees were left by growers.

None of the trees at Gridley received a spring spray. The newly hatched larvae of the midsummer brood first appeared about July 30 and reached a peak August 13 to 15. The above counts were made from the boxes immediately after picking. The total per cent of infested fruit was not ascertained since many badly injured fruits with split pits, thrips scars, and other defects—were not placed in boxes by the pickers.

All applications, which were unsupervised, were made by the growers. The sulfur was used for disease control, and the DN for red spiders.

From these data and from observations in many peach orchards over a period of years it can be concluded that, where a heavy infestation of larvae appears at picking time, about 50 pounds of 70-30 dust (70 per cent sulfur and 30 per cent basic lead arsenate) per acre, applied under ideal conditions, are necessary to give adequate protection. The majority of the commercial applications is made carelessly, with inadequate dusters, and with too small an amount of dust applied per acre to obtain satisfactory coverage of all fruit. In addition, as has been pointed out several times in this report, the infestations vary so greatly from orchard to orchard that growers often believe a good control has been obtained from what was actually a poor application. When serious outbreaks of the pest do occur, such control measures quickly show their shortcomings.

Data on Santa Rosa plums were obtained in 1942, and the results are summarized in table 20. From the dates indicated, it can be seen that the larvae were very late in hatching that particular season. While this experiment was not very conclusive in some respects, it indicates that nicotine spray powder has value in the program, especially if a poisonous residue is to be avoided. Also, it is to be noted that the 70-30 dust which is of value at this time of year likewise reduces the residue problem.

Control of Dormant Larva. After studying the results of the experimental dormant control of the twig borer, reported by other workers, it seemed desirable to test many of the newer insecticides and especially the new wetting agents, to determine their value. Also, a review was made of published reports of attempts to control other fruit insects having similar hibernating habits, particularly the codling moth, oriental fruit moth, pecan nut casebearer, and pecan leaf casebearer.

Various workers, especially Garman (1930), have tested many emulsions and toxicants in attempts to control the hibernating oriental fruit moth. The materials showing the greatest promise have been too expensive or have resulted in too much injury to the trees to be practical. Similar experiments with the hibernating codling moth have been conducted as newer chemicals became available.

Among the latest reports is that on the work of Gnadinger *et al.* (1940) in which the best results were obtained, on apples, with a spray containing 60 milligrams of pyrethrins per 100 cc of kerosene. Aqueous sprays did not give adequate penetration, even at 700 pounds pressure. The above-mentioned kerosene-pyrethrum spray would obviously cause injury to the trees; therefore, the upper two thirds of the tree was scraped, and only the lower portion sprayed. This method is, of course, impractical for the twig borer.

Bilsing (1926) has experimented with the possibility of dormant control of the pecan nut casebearer with poor results.

Table 19: PEACH TWIG BORER CONTROL ON PEACHES, 1940

Variety and location	Treatment*	Number peaches counted	Number peaches infested	Per cent infested
Haus (Gridley)	Basic arsenate of lead and sulfur 30–70, July 14. DN 1.5 per cent. Sodium fluo-aluminate 49 per cent and sulfur 49.5 per cent, July 29	734 (6 boxes) July 30	46	6.2
Haus (Gridley)	Basic arsenate of lead and sulfur 30–70. July 14	768 (6 boxes) July 30	73	9.5
Peak (Gridley)	Basic arsenate of lead and sulfur 30–70. July 14 and 23	882 (8 boxes) August 8	53	6.0
Simms (Gridley)	30–70 dust. August 6	872 (8 boxes) August 13	262	30.0
Halford (Tudor)	Xanthone, 2 lbs. to 100 gals. (with ⅓ lb. spreader). May 22	784 (8 boxes) August 14	58	7.3
Halford (Tudor)	Basic arsenate of lead, 4 lbs. to 100 gals. May 22	804 (8 boxes) August 14	34	4.2
Simms (Gridley)	DN 1 per cent, sodium fluoaluminate 60 per cent and sulfur 39 per cent. August 6	395 (4 boxes) August 15	97	24.5
Phillips (Gridley)	28 per cent basic arsenate of lead, 60 per cent sulfur, remainder inert. August 14	857 (6 boxes) August 23	89	10.3

* Dusts applied with power machine; amount per acre varied from 30 to 50 pounds.

Table 20: PEACH TWIG BORER CONTROL EXPERIMENT ON SANTA ROSA PLUMS
Marysville, California, 1942

Date treated	Material	Dosage	Average number of wilted shoots per tree*
May 23	Basic lead arsenate	4 lbs. per 100 gals. of water	2.2
June 5	Basic lead arsenate	4 lbs. per 100 gals. of water	0.1
June 10	Basic lead arsenate Sulfur	30 lbs. 70 lbs. 40 lbs. dust per acre	0.9
June 10	DND8† dust	40 lbs. dust per acre	4.7
June 12	Fixed nicotine‡	6 lbs. per 100 gals. of water	0.2
	Check		3.6

* 40 trees per plot; count made on June 19.
† Dicyclohexylamine salt of DNOCHP—1.5 per cent. Petroleum oil (70 U.R., 100 vis.)—2 per cent.
‡ Proprietary compound of about 14 per cent nicotine sulfate.

This worker, in correspondence, cites some of his recent unpublished data as follows: "I have obtained the best control by the use of an oil with a viscosity of 200 to 220. I am inclined to believe that a with this material but have not been able to get as good control on the nut casebearer which spins a tougher cocoon." Bilsing further states that the twig burning, which resulted from this mixture, is

Table 21: SUMMARY OF DORMANT SPRAY EXPERIMENTS ON THE PEACH TWIG BORER

Season	Number of different formulas applied	Number of hibernacula examined	Average mortality of all sprays	Average mortality of all checks
			per cent	per cent
1939–40..........	33	2,108	49.4	68.0
1940–41..........	48	6,491	41.5	19.4
1941–42..........	86	10,655	68.7	47.1
	167	19,254		

Table 22: PER CENT MORTALITY OF DORMANT LARVA TREATED WITH DN AND OIL* COMPARED WITH UNTREATED LARVA

Dates of sampling hibernacula	Sprayed Dec. 6, 1941	Check	Sprayed Jan. 5, 1942	Check	Sprayed Jan. 31, 1942	Check
	per cent	per cent	per cent	per cent	per cent	per cent
1941:						
December 12......	77.0	44.0	....	....	....	....
December 19......	93.4	53.4	....	....	....	....
December 26......	64.3	47.2	....	....	....	....
1942:						
January 2.........	77.4	44.0	....	....	....	....
January 9.........	88.7	41.3	66.6	53.5	....	....
January 16........	73.8	54.3	85.4	56.6	....	....
January 23†.......	....	....	....	....	....	....
January 30........	88.3	34.5	95.5	55.3	....	....
February 6........	80.8	40.3	96.4	51.6	98.2	68.4
February 14.......	86.0	45.5	97.6	47.4	90.0	66.1
Average............	81.0	44.7	88.6	52.4	94.1	67.7

* The formula used was the tri-ethanolamine salt of DNOCHP at 1:200 (30 per cent) oil emulsion (80 vis., 70 U.R.) at 2 per cent, and a 10 per cent solution of wetting agent at 1:500.
† Heavy rain; no sample taken.

peach tree would not withstand an oil of that viscosity, however. I have also obtained very good control with an oil having a sulphonation of 70 and a viscosity of 108. To this oil (at 2 per cent) I have added about 2 pounds of dinitro-ortho-cyclo-hexyl-phenol to each 100 gallons of water. We have obtained practically 100 per cent control on the leaf casebearer a serious disadvantage, and that water-soluble dinitro compounds show greater promise.

The dormant work reported below was begun in December, 1939, and continued for three winters. The experiments were conducted in Colusa, Yuba, and Solano counties with peaches, nectarines, plums, and almonds. The majority of the work

Table 23: MOST EFFECTIVE DORMANT SPRAYS FOR THE CONTROL OF PEACH TWIG BORER LARVA ON PEACHES (1939–40) AND ON ALMONDS (1941–42)

Material and dosage	Date sprayed (1) and examined (2)	Number hibernacula	Per cent mortality
1. DNOCHP, 1:600. Dormant oil (100 vis., 72 U.R.) emulsion 2 per cent	(1) Dec. 15, 1939 (2) Dec. 29, 1939	137	93
2. DNOCHP, 1:200	(1) Jan. 29, 1940 (2) Feb. 3, 1940	160	90
3. DNOCHP, 1:600	(1) Jan. 29, 1940 (2) Feb. 3, 1940	143	100
Check	(2) Dec. 29, 1939	46	90
4. DNOCHP (Tri-ethanolamine salt), 1:400	(1) March 5, 1940 (2) March 8, 1940	31	100
5. As above with pine oil 1 per cent, 1:800	(1) March 1, 1940 (2) March 4, 1940	12	100
6. Pyrethrum extract (about 0.5 per cent pyrethrum), 10 per cent wetting agent, 1:400. Pine oil, 1 per cent	(1) March 5, 1940 (2) March 8, 1940	28	100
Check	(2) March 4, 1940	32	53
7. Rotenone (0.25 per cent by wt.) in oil emulsion (82 vis., 76 U.R.), 4 gals. Wetting agent, 4 oz., blood albumen, 4 oz. to 100 gals. water	(1) Jan. 9, 1941 (2) Jan. 20, 1941	118	93
8. DNOCHP (T.E.A. salt) 1:200. Oil emulsion, 82 vis., 76 U.R., 2 per cent. Wetting agent, 4 oz.	(1) Jan. 10, 1941 (2) Jan. 24, 1941	120	90
9. Sodium dinitro cresylate (30 per cent) 1:200. Oil emulsion, 82 vis., 76 U.R., 2 per cent. Wetting agent, 4 oz.	(1) Jan. 10, 1941 (2) Jan. 27, 1941	109	91
Check	(2) Jan. 24, 1941	121	19
10. Sodium dinitro cresylate 30 per cent, 1:200. Oil emulsion, 80 vis., 73–79 U.R., 4 per cent	(1) Jan. 16, 1942 (2) Jan. 27, 1942	134	91
11. DNOCHP (T.E.A. salt) 1:200. Oil emulsion 80 vis., 73–79 U.R., 4 per cent	(1) Dec. 22, 1941 (2) Jan. 5, 1942	71	100
Check	(2) Jan. 5, 1942	126	77
12. DNOCHP (T.E.A. salt) 1:200. Oil emulsion, 105 vis., 70 U.R., 4 per cent	(1) Jan. 16, 1942 (2) Jan. 28, 1942	98	100
Check	(2) Jan. 20, 1942	129	29.1

Table 23—Continued

Material and dosage	Date sprayed (1) and examined (2)	Number hibernacula	Per cent mortality
13. DNOCHP (T.E.A. salt) 1:200. Oil emulsion, 80 vis., 73–79 U.R., 4 per cent	(1) Jan. 16, 1942 (2) Jan. 27, 1942	91	90.9
14. DNOCHP (T.E.A. salt) 1:200. Oil emulsion, 80 vis., 80 U.R., 4 per cent	(1) Jan. 6, 1942 (2) Jan. 13, 1942	67	95.5
15. DNOCHP (T.E.A. salt) 1:200. Oil emulsion 105 vis., 70 U.R. (cut 25 per cent with kerosene), 4 per cent	(1) Jan. 9, 1942 (2) Jan. 29, 1942	102	93.2
16. DNOCHP (T.E.A. salt) 1:200. Oil emulsion 80 vis., 73–79 U.R. (cut 25 per cent with kerosene), 4 per cent	(1) Jan. 16, 1942 (2) Jan. 28, 1942	110	90.6
17. As above with 10 per cent wetting agent, 1:1500	(1) Jan. 16, 1942 (2) Jan. 28, 1942	78	95.8
Check	(2) Jan. 28, 1942	68	55.3
18. As above but oil emulsion at 2 per cent	(1) Jan. 9, 1942 (2) Jan. 27, 1942	115	98.4
19. As above with oil emulsion 105 vis., 70 U.R. (cut 25 per cent with kerosene), 2 per cent	(1) Dec. 18, 1941 (2) Jan. 5, 1942	87	92.1
Check	(2) Jan. 5, 1942	76	46.9
20. DNOCHP (T.E.A. salt) 1:200. Kerosene, 1:200. 10 per cent wetting agent, 1:1500	(1) Jan. 9, 1942 (2) Jan. 27, 1942	123	98.4

was concentrated at Arbuckle on almonds. Two progress reports were made on this work by the writer in "Almond Facts" (Bailey, 1941, and 1942).

Unless otherwise indicated, the applications were made with a knapsack sprayer to young trees three to five years old. From 5 to 15 trees were sprayed with each material or mixture, the number depending on the visible number of hibernacula present, in order that about 100 larvae be subjected to each treatment. The entire tree was sprayed with a uniform coverage. After sufficient time had elapsed to make it possible to determine definitely the dead larvae, the hibernacula were cut from the test trees and from adjacent unsprayed trees, taken to the laboratory, and examined under a microscope.

The following types of insecticides used in these tests were found to have little or no value in dormant control: thiocyanates, alkyl phenol, several proprietary mixtures of dinitro phenols and cresols (both dry and liquid), three proprietary pyrethrum extracts, two types of rotenone concentrates in solvents, nicotine sulfate, dichloropentane, ortho-dichloro-benzene (saturated solution in kerosene), pine oil, liquid lime-sulfur (at 2, 6, 8, and 10 per cent), liquid lime-sulfur at 2 per cent with 4 per cent oil emulsion (80 vis. and 79 U.R.); and heavy oil emulsions listed at the top of the next page.

100–110 vis.	60–70 U.R.
130 vis.	73 U.R.
144 vis.	78 U.R.
150 vis.	60–70 U.R.
160 vis.	73 U.R.
175 vis.	60–70 U.R.
200 vis.	60–70 U.R.

Several oil emulsions in common use in the range of 80–105 vis. and 70–80 U.R. were used at 4 per cent alone with poor results.

Many of the materials were experimental or were special preparations, and certain others, offered for sale at the time, are not on the market at present. The contact toxicants were used in various standard dilutions—for instance, 1:200, 1:400, 1:800, with and without spreaders and wetting agents, as well as with and without oil emulsions. The heavy oil emulsions, used at 2 to 6 per cent, did not give satisfactory penetration. They are dangerous to use in the delayed dormant period. Kerosene alone evaporates too quickly to give adequate penetration of the bark. A summary of this work is given in table 21.

Following the first two winters of work, one of the most satisfactory formulas was used on almonds in a test to determine the best time to apply such dormant sprays. Three applications were made about one month apart. At weekly intervals thereafter, approximately 100 hibernacula were cut out of the bark of the sprayed and unsprayed trees and examined under the microscope to determine the per cent of mortality. The results are presented in table 22. It can be seen from these data that when the spray was applied at the latest possible date, the control was better.

The most effective formulas used in these experiments are listed in table 23 with the per cent control (or mortality) obtained. No injury to the trees with any of these mixtures was observed. The mortality in the checks was from parasites.

A preliminary trial was made with dry-mix dinitro powder which showed promise. Following this trial, 16 combinations of the material with various oil emulsions, kerosene, and diesel fuel oil, with and without a spreader and/or

Table 24: DORMANT SPRAY EXPERIMENTS FOR THE CONTROL OF PEACH TWIG BORER LARVA WITH DN AND OIL

Material and dosage	Date sprayed (1) and examined (2)	Number hibernacula	Per cent mortality
1. DNOCHP powder,* 2 lbs. Diesel fuel oil, 6 per cent Dried blood, 8 oz. to 100 gals. water	(1) Jan. 15, 1942 (2) Feb. 9, 1942	111	95.3
Check	(2) Jan. 21, 1942	87	11.6
2. DNOCHP powder,* 1 lb. Oil emulsion, 80 vis., 80 U.R., 4 per cent Oxalic acid crystals, 2 oz. to 100 gals. water	(1) Jan. 15, 1942 (2) Feb. 9, 1942	115	97.5
Check	(2) Jan. 21, 1942	92	3.8
3. DNOCHP (T.E.A. salt),† 1:300. Oil emulsion, 80 vis., 80 U.R., 4 per cent Oxalic acid crystals, 2 oz. to 100 gals. water	(1) Jan. 15, 1942 (2) Feb. 9, 1942	107	91.4
Check	(2) Feb. 9, 1942	97	8.0

* 12.5 per cent active ingredient. † 30 per cent active ingredient.

wetting agent, were applied to plums with a power sprayer. The three combinations giving better than 90 per cent control are listed in table 24.

This plot was studied throughout the spring. A wilted twig count made on April 2 is shown in table 25.

These data would seem to indicate that the DN powder did not give quite such good results as the liquid concentrate by the time the overwintering larvae had all emerged. The individual applications were not replicated. A practical control was obtained, however.

Control with DDT. In the early spring of 1946 a small-scale test of wettable DDT powder on the larvae was made in the laboratory. Newly leafed out terminal twigs of prune which had been sprayed with wettable DDT powder (1 pound of DDT per 100 gallons of water) were brought into the laboratory. Twig borer larvae, about one half to two thirds grown were caged on these shoots. All larvae, whether crawling on the bark or on the leaves, became excited and very active within 20 minutes after contacting the residue. Many individuals dropped from the shoots and made no attempt to return. No actual feeding was observed, and all larvae were dead in 24 to 36 hours. The same results were obtained when this test was repeated. Furthermore, it was observed that many of the larvae exuded salivary fluid from the mouth a few minutes after contacting the DDT.

The DDT wettable powder was tested on a small scale in 1946 and 1947 against the spring broods in the field on young almonds. The data, presented in tables 26 and 27 were based on the shoot damage caused by a rather light infestation. It indicates, nevertheless, that DDT gives considerable promise in the control of the twig borer, in every instance being slightly better than the basic lead arsenate.

Furthermore, the widely used wettable DDT powder was compared with the basic lead arsenate in the almond orchard in which we have records for several years (table 17). It can readily be seen that the infestation was too light for us to have arrived at any conclusion (table 28). No difference in the red spider infestation was noted in any of the plots. In parts of Stanislaus County in 1946 and 1947, however, twig borer infestations were rather severe on cling peaches. In this area, DDT is being more generally used each season, since basic lead arsenate apparently fails to give control, even when four applications are made. The reason is unknown unless an arsenic-resistant strain of twig borer is being developed here. In no case known to us has DDT given poor results when used against the peach twig borer. Growers feel that if such obstinate twig borer infestations can be controlled by DDT, red spider injury can be reduced if necessary by spraying after harvest.

For many years it has been a standard practice not to apply basic arsenate of

Table 25: WILTED TWIG COUNT ON PLUMS
Marysville, California, April 2, 1942
(Sprayed as indicated in table 24)

Plot	Total trees counted	Total injured twigs	Average per tree	Per cent control
1	24	87	3.6	68
Check	19	216	11.3	..
2	23	40	1.7	88
Check	24	391	16.2	..
3	24	28	1.1	93
Check	24	376	15.6	..

lead spray to peaches within 60 days of harvest because of the potential residue of lead and arsenic. Studies made by Plank (1933), however, proved that "peaches sprayed from one to four times with basic arsenate of lead up to within five days before harvest never contain more than negligible minute traces of arsenic when subjected to the accepted peeling and washing process now commercially used."

On plums, the poisonous and objectionable visible residue problem has been circumvented by the use of rotenone and nicotine sprays. The sulfur and basic lead arsenate dust (70–30) has been commonly used in canning peach districts during early summer with no objectionable residue left.

In 1945, through the facilities of the Division of Entomology and Parasitology samples of peaches were analyzed from orchards sprayed with DDT for adult mosquito control before picking operations. The residue on the fruit was found to be 2 to 6 p.p.m. (parts per million). During the summer of 1946 further DDT residue studies were made in coöperation with the Division of Chemistry (at Davis), the Agricultural Extension Service office at Modesto, and the Research Department of the California Packing Corporation. The data, listed in table 27, are from peaches.

From these preliminary data it can be seen that the present forms of DDT, applied at the strengths employed, leaves a very small amount of residue. No residue was found on the lye-peeled sprayed fruit, and determinations were not run

Table 26: PEACH TWIG BORER CONTROL* WITH DDT ON ALMOND
Dixon, California, 1946

Treatment	Variety	Row	Count before spraying (May 2)†	Count as worms begin feeding (May 27)	Count at end of larval activity (June 18)	Per cent control
Check	Peerless	1, 2	2.6	0.8	2.5	...
DDT (50 per cent) Wettable—2 lbs. ½ lb. spreader 1 pt. kerosene to 100 gals.	Texas	3, 4	5.1	0.0	0.15	94.0
Check	Nonpareil	5, 6	1.8	0.05	1.3	...
DDT (10 per cent) and Wettable sulfur (83 per cent) 10 lbs. to 100 gals.	Peerless	7, 8	4.3	0.0	0.05	96.1
Check	Jordanola	9, 10	3.2	0.8	3.8	...
Check	Texas	11, 12	2.0	0.6	3.1	...
Basic lead arsenate 4 lbs., ½ lb. spreader to 100 gals.	Nonpareil	13, 14	2.9	0.15	0.5	83.8

* Counts based on number of wilted shoots per tree (20 trees per plot) and average only given. Trees were sprayed May 14 as eggs were hatching.
† This damage was caused by the spring brood and is an index of the infestation. No red spiders were present before or after spraying. Following spraying, very cool, rainy weather delayed larval activity and washed off considerable deposit.

Table 27: PEACH TWIG BORER CONTROL WITH DDT ON ALMOND

Arbuckle, California, 1947

Spray material	Date sprayed	Average wilted shoots per tree*	Per cent control	Remarks
Wettable DDT (50 per cent): 2 lbs. to 100 gallons	Mar. 13	2.3 (20 trees)	73	The March 13 spray for the emerging larvae should have been applied about 5 days earlier for the best results, but the weather did not permit.
Basic lead arsenate: 4 lbs. plus 1 qt. liquid spreader to 100 gallons	Mar. 13	3.9 (20 trees)	55	No red spider infestations developed in this plot. Wilted shoot count made Mar. 25.
Check		8.7 (20 trees)		
Wettable DDT (50 per cent): 2 lbs. to 100 gallons	Apr. 30	0.08 (58 trees)	84	The April 30 spray was applied after all moths had emerged in this area and before any wilted shoots were seen (the first larva was found May 5).
Basic lead arsenate: 4 lbs. plus 1 qt. liquid spreader to 100 gallons	Apr. 30	0.11 (54 trees)	78	No red spider build-up in this orchard. Wilted shoot count made May 22.
Check		0.51 (56 trees)		

* Five- to seven-year-old almond trees.

Table 28: PEACH TWIG BORER SPRAY PLOT ON NONPAREIL ALMONDS*

Arbuckle, California, 1947

Date sprayed	Stage of growth	Material	Dosage	Per cent of injury to nuts
March 13	Late jacket	Wettable DDT (50 per cent)	2 lbs. to 100 gals. of water	0.3
	Check			0.3
March 13	Late jacket	Basic lead arsenate Liquid spreader	4 lbs. to 100 gals. of water 1 qt.	0.3
	Check			0.2
April 30		Wettable DDT (50 per cent)	2 lbs. to 100 gals. of water	0.3
	Check			0.5
April 30		Basic lead arsenate	4 lbs. to 100 gals. of water	0.7
	Check			0.3

* In this test, 26,222 nuts were hulled, cracked, and counted.

Table 29: DDT RESIDUE ANALYSIS ON PEACHES

Sample	Variety	Treatment	Date picked	Condition of fruit	DDT residue in parts per million
1	Palora	May 15, wettable spray (1 lb. actual DDT to 100 gallons of water)	July 30	Ripe	2.0
2	Phillips	June 26, as above	July 30	Green	1.8
3	Palora	July 19, dusted. DDT, 5 per cent and sulfur 50 per cent, about 30 lbs. per acre	July 30	Ripe	1.5
A	Phillips	August 15, wettable spray (1 lb. actual DDT to 100 gallons water, 300 gallons per acre)	Aug. 30	Ripe	5.45 (Average of duplicates) as received
A	Phillips	As above	Aug. 30	Ripe	0.0 (Average of duplicates) lye-peeled
B	Phillips	As above	Aug. 30	Ripe	2.45 (Average of duplicates) as received
B	Phillips	As above	Aug. 30	Ripe	0.0 (Average of duplicates) lye-peeled
C	Phillips	As above	Sept. 6	Ripe	2.3 (Average of duplicates)
D	Phillips	As above	Sept. 6	Ripe	2.9 (Average of duplicates)
4	Phillips	July 30 and August 15 DDT 5 per cent, sulfur 50 per cent, 33 lbs. per acre	Sept. 11	Ripe	2.1

on the canned peaches. It is unknown whether or not, under average cannery conditions, the DDT residue in the lye-peeler, when handling a large volume of DDT-sprayed fruit, would accumulate sufficiently to contaminate the commercial pack.

DISCUSSION

The most outstanding fact observed in this entire study is the great variation in the twig borer population. This fact is very evident in studying the work of Clarke, Duruz, and others, as well as in our own studies of parasitism and degree of injury, in both the test and the control plots. Even during the most severe epidemic of the twig borer on record, Mackie and Jones (1931) showed that the degree of injury varied from 0.1 per cent to 20.7 per cent on 110 properties in Sutter and Yuba counties. Since 1932 no extensive survey of this type has been made, but the irregularities of outbreaks of this pest in the principal peach-growing districts are well known. The injury is not only unpredictable from year to year but also from district to district.

Our studies have been more closely concentrated on almonds, and the facts gathered on this crop and reported in the tables of this study well bear out this

habit of great variation. Wide variation occurs not only in the density of hibernacula and parasitism, but in the number of wilted twigs and number of pupae as well as in the degree of infested fruit, even in adjacent plantings. The percentage of injured soft-shelled nuts varies widely every year in different districts, as is pointed out by the Exchange records. Our winter studies show that a consistently high population is maintained in Colusa and Butte counties and that, in general, to the south and west progressively the infestations become somewhat lighter. The Paso Robles district suffers no loss from this pest and the Santa Clara Valley, lower San Joaquin Valley, and southern California areas rarely report any economic damage.

Following a comparative study of the data gathered from the 1937, 1938, and 1939 spray plots at Arbuckle, considerable variation was noted in the degree of injury occurring even from row to row. In 1940 and 1941 records were carefully kept to determine the degree of variation in the infestation in the experiments reported in table 17.

An analysis of these data—based on a count of over 19,100 almond meats—indicated a great range of injury from row to row and plot to plot in the same orchard, in two successive seasons, one of low and one of medium injury. This variation tends to throw doubt on the reliability of the data obtained in the spray plots since replications (or the Latin square method) were not used. The great amount of work involved in collecting and dissecting the hibernacula, as well as in the harvesting, made it impossible to replicate the various sprays.

We feel, however, and it has been demonstrated, that a practical reduction in the number of overwintering larvae can be accomplished by delayed dormant applications of an oil emulsion of about 80 vis. and 80 U.R. with a toxicant, such as dinitro, on almonds and plums. At least many materials have been eliminated, even though DDT and other newer chemicals are yet to be thoroughly tried. The matter of cost of such an application is still a limiting factor as compared with basic lead arsenate. The advent of new spray materials for disease control also raises many unanswerable questions of compatibility of the new chemicals and the possibility of more efficient combinations of insecticides and fungicides.

It was hoped that a determination of the degree of parasitism of the hibernacula in January would furnish a good basis for predicting the severity of the infestation the following summer. However, as pointed out above, the variation is so great that such data are not too reliable. Furthermore, if conditions are very favorable during the growing season, a moderate number of overwintering larvae may build up to a sizable infestation by midsummer. There is no obvious or regular cycle of epidemics of this pest.

The year-to-year variation in the degree of injury to varieties of plums and peaches depends on the time of ripening in relation to the appearance of the midsummer brood. This is also true of apricots. For instance, in some years the fruit ripens at the peak of hatching of a brood; the considerable amount of damage which results could not have been predicted in February solely on the basis of the degree of parasitism. Also, if the crop is heavy, or light, the total injury is proportionately small or great with a given number of larvae. One of the principal factors influencing the severity of outbreaks is economic—the price of fruit which, if good, is usually reflected in a conscientious local spray program which keeps the worm population down to a minimum.

At present, biological control by parasites—as has been accomplished with certain scales and other insects—does not seem practical, although there is room for additional work on this phase of control. The native parasites operating so effectively in the coastal areas and in the lower San Joaquin Valley have their limi-

tations. The relative importance of the twig borer will determine the desirability of searching abroad for additional and more effective parasites.

Preliminary tests with wettable DDT sprays indicate that it is somewhat better than the widely used basic lead arsenate. If DDT comes into general use, it is almost sure to throw certain local insect and red spider populations out of balance, particularly if applied after early May. Experience only can indicate whether the advantages of DDT will overcome the disadvantages in the control of the peach twig borer.

SUMMARY

The peach twig borer, *Anarsia lineatella* Zell., is an introduced insect. It has been an important insect pest in California for over sixty years. Its two most important host plants are the peach and the almond.

Irregular epidemics have occurred in the principal peach-growing areas of the great valleys of California during this period. Local infestations of major proportions often arise in plum and almond orchards in the upper San Joaquin and Sacramento valleys. It is found in all peach- and almond-growing areas of this state as well as in nearly all deciduous fruit sections of the United States.

In epidemic years, a 50 per cent loss of peaches is common, and 20 to 30 per cent damaged meats of soft-shelled almonds is frequently encountered in the Sacramento Valley. The damage to plums and nectarines is usually less and more localized.

Great irregularity is observed in the infestations. This makes the prediction of outbreaks impossible with present methods of control.

The injury to the trees themselves is unimportant as compared with the direct damage by midsummer broods to the ripening fruit.

The dark-gray moth is about 5/16 inch long. The minute yellowish-white, oval eggs are laid on bark, leaves, and fruit, singly or in small groups. The larva is chocolate brown in color, with a black head, and is about 3/8 inch long when full grown. The naked pupa, usually found under the bark, is dark brown and about 1/4 inch in length.

During the summer season the approximate length of the life history stages is as follows: egg, 5 to 7 days; larva, 10 to 20 days; pupa, 6 to 7 days; adult longevity, about 10 days. The winter is passed in a cell—the hibernaculum—hollowed out in crotches of two-year-old wood and lightly covered with frass and silk. Emergence of these immature larvae takes place at blossoming time. There is a brood in May, additional broods with a wide spread in July and August, and a partial brood in September. Some larvae from each brood form hibernacula.

There are many known parasites and predators of various stages of the peach twig borer. The two most important attack the dormant larva, namely the hymenopteran, *Hyperteles lividus* (Ashm.), and the grain or itch mite, *Pediculoides ventricosus* (Newport).

The principal control measure is by direct chemical control with insecticides applied against the feeding larva during early spring and in May. Spraying with basic arsenate of lead, 3 to 4 pounds per 100 gallons of water, is the most widely used program. Wettable 50 per cent DDT spray powder has been used on a small experimental scale only and may, in the future, with limitations, partly replace the lead arsenate. The potential poisonous residue problem on market fruit must be remembered; therefore, summer sprays should be applied with caution. Preharvest control may be obtained on canning peaches with the generally used 70–30 dust (70 per cent sulfur and 30 per cent basic lead arsenate) if a modern power duster is employed, and about 50 pounds of dust applied per acre in mature orchards. DDT dust of 5 per cent strength likewise has shown great promise, but should be used on a small scale only until

more data are available on its relative value and limitations. In general, the use of DDT in orchards after late May tends to increase the red spider hazard. Experimental work with delayed dormant sprays has demonstrated that a practical reduction in the number of overwintering larvae can be accomplished by the use of an oil emulsion of about 80 vis. and 80 U.R., with a toxicant such as dinitro on almonds and plums.

RECOMMENDED CONTROL PROGRAM

Little change can be made in the control recommendations for the peach twig borer at this time. Many new chemicals have been introduced into the field of insecticides in recent years, but the majority is not adapted to this insect. Preliminary experimental work with DDT has been conducted, but not enough is known concerning its value against the twig borer to recommend its general use in place of basic lead arsenate.

1. Dormant application. Until the advent of DDT, the newest method of attack was delayed dormant applications of dinitro compounds with medium spray oil emulsion. Growers have made little use of this method of control. This type of treatment *must not be used* on peaches. On prunes and plums it has a place, especially where aphid eggs and scale also are being treated during the dormant season. Heavy infestations on almonds may also be markedly reduced by such a spray. To obtain the best results, apply the following formula after about January 15 and up to the early green bud stage:

Sodium dinitro-o-cresylate (30 per cent) 1½ to 2 qts. (1:200 or 1:300)
or wettable dinitro powder (DNOCHP, 20 to 30 per cent) .... 1 pound to 100 gallons
Medium oil emulsion (about 80 vis., and 80 U.R.) approximately 85 per cent actual oil .... 2 to 3 gallons
Water .... 100 gallons

2. Prebloom spray. Where light infestations occur, annual early basic lead arsenate sprays apparently hold down the pest. This application is widely used on apricots. In wet seasons such early treatment is not physically possible and rains reduce its effectiveness. Heavy infestations cannot be controlled by one early application. The spray should be applied from the bud-swelling stage to the popcorn stage.

Basic lead arsenate ..... 3 to 4 pounds
Spreader or sticker .... 1/3 pound or 1 quart
Water .... 100 gallons

NOTE: If the basic lead arsenate is used with bordeaux, no spreader is necessary. Also, when there is a shortage of help and a large acreage must be covered between rains, the "Vapo" type of application—employing oil concentrate, 10 to 12 gallons and 10 to 12 pounds of basic lead arsenate per acre—may be used with considerable success for the first brood. Our experiments, as well as those of others, have indicated actually a very poor kill of the larvae with lime-sulfur. In the central and lower portions of the San Joaquin Valley, the worms become active somewhat earlier and prebloom sprays are very effective.

3. Jacket spray. This spray is particularly desirable on apricots, plums, and peaches after petal fall. Use basic lead arsenate as above.

4. May spray. The time of application (May 5 to 25) varies from year to year and is best correlated with the first wilted shoots seen on young trees and replants. Use powdered spreader (or wettable sulfur) and avoid "deposit builders" or oils. Where mixed varieties occur, all trees must be sprayed. *Both the jacket spray and May spray* (basic lead arsenate as above) *are necessary in many peach-growing districts.*

5. Midsummer treatment. Substitutes for the basic lead arsenate spray must be used (except on almonds) to avoid poisonous residue. The 70–30 dust is widely used on peaches. On mature trees, 50 pounds per acre are necessary for adequate protection. On plums, spraying with rotenone powder (3 to 5 pounds, depending on strength of rotenone per 100 gallons of water) or with about 6

pounds of fixed nicotine spray powder (14 per cent strength) about a week before picking has given excellent results; each variety must be sprayed as it ripens. Such crops should be treated as soon as any small stem worms are observed on the first fruits to turn color.

6. DDT. This compound has been tested against nearly all our important pests, including the twig borer. To date, we have used the wettable DDT powder in controlled tests on almonds only. Some growers have used 2 to 4 pounds of the wettable powder (or 1 pound of actual DDT) to 100 gallons of water, as well as a 5 per cent dust, on canning peaches in July and August, and report excellent control during 1946 and 1947. The 5 per cent DDT dust (particularly with 50 per cent sulfur) appears to give excellent promise of stopping the small larvae at harvest time on late cling peaches.

As is true with any new material or method, refinements and modifications are necessary, partly by trial and error, over a period of years before the best standard of mixture and strength can be established. Therefore, the above suggestions for DDT are only preliminary. Growers should keep this in mind, together with the fact that red spiders and aphids are a serious potential problem where DDT is employed. We do not have sufficient data to recommend the wholesale use of DDT for the peach twig borer at present, and before using it on fruit trees, growers should obtain a clearance from the canner or shipper.

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141

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